Integrated Pest Management in Developing Countries

Experience and Prospects

Consultants' report commissioned by the
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Contents

Foreword

The initiative leading to the publication of this report on integrated pest management (IPM) in developing countries stemmed from a crop protection conference held by CAB International in the United Kingdom in April 1989, and from the mid-term meeting of the Consultative Group on International Agricultural Research (CGIAR) in Australia in May of the same year. The first meeting, attended largely by scientists, highlighted the problems of limited adoption of IPM in developing countries; the second, a forum for donor agencies, suggested an approach to addressing the problem—initially through the establishment of a small task force. The latter comprised interested representatives from the following development assistance agencies: IDRC, USAID, ODA, ACIAR and FAO (*see* Appendix 1 for abbreviations). Funds for the IPM Task Force's operations and associated consultancies came from these five organizations.

The prime concern driving this initiative was the limited adoption of IPM in the developing countries of the tropics (as well as in many developed countries), despite the very large body of relevant knowledge that has accumulated, particularly over the past two decades. Environmental and human health concerns over excessive pesticide usage; the increasing resistance of pests to existing chemicals; and the limited scope for production of new, environmentally benign pesticides are among the many compelling reasons that have been repeatedly stressed for turning to IPM.

Most IPM activities, from research and development to extension and adoption, take place within national programmes, supported from many funding sources. Because of a lack of co-ordination at the international, regional and, in some cases, even national levels, there have been few opportunities to take comprehensive stock of the reasons for the lack of adoption of IPM in developing countries, or to develop rational approaches for overcoming these constraints.

The IPM Task Force was therefore asked to evaluate past and present attempts at IPM in representative developing countries, with particular emphasis on reasons for lack of success, and to identify constraints on wider adoption of IPM where pilot work had been successful. Armed with this information, the Task Force was to propose criteria for successful IPM and strategies for achieving this through the establishment of appropriate institutional mechanisms in national programmes, assisted by co-ordinated efforts of international development agencies and other necessary support. As a major first step in this initiative, the Task Force commissioned a group of consultants to undertake the required background studies and prepare a series of working papers and reports. The Task Force was fortunate to obtain the services of individuals with strong international reputations in their respective fields for this work. They were the Group Convenor, Michael Way, and Clive James, Paul Teng, John Terry, David Groenfeldt and Malcolm Iles (*see* Appendix 2).

This report is the outcome of their efforts and, reinforced by inputs from others associated with the programme, will provide a firm basis for other activities now under way in this initiative. It is intended to stimulate discussion of issues important to the implementation of IPM in developing countries of the tropics; it reflects the personal views of the authors, and does not necessarily reflect the views of the members of the IPM Task Force.

G.H.L. Rothschild
29 January 1991

Acknowledgements

The consultants were appointed from 1 October 1989. Some members of the Consultants' Group met on 6-8 October at FAO, Rome, and all from 6-10 November at the offices of the International Food Policy Research Institute, Washington DC, where they were joined by Gabrielle Persley, Secretary of the Task Force. In Rome the Group benefited greatly from discussions with Lukas Brader, Chief of the Plant Protection and Production Division, FAO, and members of his staff. There were also useful discussions with participants at a subsequent meeting of the FAO/UNEP Panel of Experts on Integrated Pest Control. The Group is most grateful to FAO for providing administrative assistance in Rome.

In Washington the Consultants' Group was joined by William Furtick of USAID and W. Barclay of Greenpeace for part of the time. The Group is greatly indebted to the International Food Policy Research Institute (IFPRI) for providing excellent facilities for the meeting, and for secretarial assistance. Particular thanks are due to Ms L. Goldberg, IFPRI's conference co-ordinator, for these arrangements.

The Group is very grateful to the International Development Research Centre (IDRC) Regional Office in Singapore for hosting firstly, the consultant group meeting on 1-3 December 1989, and secondly, the Task Force meeting on 4-5 December 1989. Without the excellent support of IDRC and ACIAR secretarial staff, much of the deliberations would not have been documented.

The membership of the Consultant Group is given in Appendix 2. The consultants are grateful to many people for helpful advice and information, particularly S. Barbosa, C. Farrar, D. Mackenzie, S. Mboob, G. A. Norton, G. Schulten, M. Vaughan and A. Youdeowei. The Group is also most grateful to scientists who, at very short notice, completed pest management questionnaires. Their names are given in Appendix 5.

Summaries

SUMMARY

Current global losses in crop production due to pests are of the order of US$ 300 billion annually. The estimated annual cost of pesticides used in agriculture is US$ 20 billion. The costs of pesticides to developing countries are a major drain on foreign exchange at the national level, as well as requiring a significant outlay by farmers at the village level. The estimated expenditure by international development agencies on pest control projects in 1988 was at least US$ 150 million.

Integrated pest management (IPM) is the strategy widely recommended, although less widely used, for the reduction of pest damage through the careful integration of a number of available pest control techniques. As a practical reality, it may be defined as 'the farmer's best mix of control tactics in comparison with yields, profits and safety alternatives'. Its aim is to reduce the use of chemical controls, and to maximize the use of the biological and cultural components, including host-plant resistance and biological control agents. In tropical agricultural systems, IPM aims to provide an environmentally sound means of pest control, requiring fewer external inputs to the system.

This report discusses ways to increase efficiency in using the substantial funds being invested in pest control by international development agencies, with a consequent reduction in the losses due to pest attacks, and reduced expenditure on pesticides. The key questions it seeks to answer in relation to the use of IPM in developing countries are:

- What are the lessons from past experience?
- What opportunities are available and what needs to be done in the future to ensure better delivery of pest management systems?
- What new or improved institutional mechanisms are required to ensure the delivery of better pest management systems?
- What actions should international development agencies take in their future support for IPM, in order to ensure more efficient use of resources?

The experience gained in several countries, farming systems and crops was surveyed during the preparation of this report. Despite significant investments over the past 20 years by national governments and international development agencies in programmes designed to promote the application of IPM in the tropics, the results have been disappointing. Major reasons for failure have been:

- inadequate problem definition, leading to poor project design;
- inappropriate research which fails to design technologies suited to small farmers;
- fragmentation of effort within a country, where research, extension and plant protection are often the responsibilities of different departments within governments;
- inappropriate government policies, such as chemical price subsidies, which favour pesticide use.

Amongst international development agencies (both bilateral and multilateral) there have been few successful attempts to define a significant pest problem, and bring together a 'critical mass' of resources and expertise to aid its solution. There have, however, been a number of successes in the development and use of IPM in the tropics, notably with rice in South-East Asia, soybean in Brazil, and cotton in Zimbabwe. The common features of successful projects have been:

- clearly defined target(s) and well-focused programmes of implementation;
- pest control strategies suitable for use by small farmers;
- good links between research and extension;
- adequate infrastructure;
- availability of trained personnel at all levels of project management;

- suitable training programmes;
- sustained funding.

The aim of any international initiative on pest management should be to encourage the delivery of more effective pest control programmes based on the sensible use of IPM strategies. Some of the possible targets which would benefit from the application of such an approach are identified. They include vegetables in Asia and Central and South America; cotton in Africa; soybean in South America; and cocoa in West Africa, South-East Asia and Central and South America.

Several different institutional arrangements are examined to highlight the options which favour better delivery of IPM programmes. These are:

Option 1: Establishment of a donor consortium to promote implementation of IPM in developing countries.

Option 2: Establishment of a new International Council for IPM with representation from client countries, and also from IPM experts, FAO, the donor community, NGOs and the private sector. An International Council would implement its policies and assist national programmes to define needs and to design more effective IPM programmes by creating an IPM Resource Group, with teams permanently based in Asia, Africa and Latin America, and also with senior liaison officers in North America and Europe. The annual estimated cost is US$ 2.5 million.

Option 3: Similar to Option 2, but initially establishing a Resource Group only in Asia to assist national programmes, on the basis that expansion to Africa and Latin America will be contingent upon success in Asia. The annual estimated budget is US$ 750,000.

Option 4: Establishment of a new International Consortium for IPM of donor agency members and representatives from international and national government organizations, including client countries. The Consortium's policies of helping client countries to design, fund and undertake more effective IPM on important crops would be implemented through an IPM Action Group. The Action Group would comprise a core of about five key staff of appropriate disciplines, some seconded from donor agencies. They would be based at a centre of excellence for IPM, but would be mostly working with FAO Regional Plant Protection Officers and with other international and national organizations in recipient countries. The annual estimated cost is US$ 1.5-2.0 million.

Option 5: A separate institution to implement and execute (as well as facilitate) more effective IPM programmes at the field level. This would require significant expenditure to establish and would compete with existing institutions such as FAO and the many bilateral agencies which are already engaged in the implementation of IPM programmes in Africa, Asia and Latin America.

Given (i) the magnitude of current losses due to pests; (ii) the IPM opportunities currently available for decreasing the financial and environmental costs associated with the use of pesticides in developing countries; and (iii) the limited successes from large investments by national governments, bilateral and multilateral development agencies in pest management projects, it is strongly recommended that new approaches be explored to ensure that better pest management practices are made available to farmers in the developing countries of the tropics.

RESUME

A l'heure actuelle, les pertes globales de production des cultures par suite des parasites sont de l'ordre de 300 milliards de $ US/an. Il est estimé que le coût annuel des pesticides mis en oeuvre dans l'agriculture s'élève à 20 milliards de $ US. Dans les pays en voie de développement, les coûts des pesticides constituent une hémorragie sur les devises au niveau national, tout autant qu'ils exigent des débours importants de la part des exploitants agricoles au niveau local. On estime que les dépenses effectuées par les agences internationales de développement pour les projets de lutte antiparasitaire en 1988 s'élevaient à au moins 150 millions de $ US.

La lutte intégrée (IPM) est la stratégie largement préconisée bien que moins utilisée pour réduire les dégâts des parasites, par le biais de l'intégration judicieuse des diverses techniques disponibles de lutte contre les nuisibles. En tant que réalité pratique, on peut la définir comme étant 'la combinaison optimale de tactiques de lutte de l'exploitant agricole par rapport aux rendements, bénéfices et alternatives de sécurité'. L'objectif de l'IPM est la réduction de l'emploi des produits chimiques et la maximisation de l'emploi des éléments constitutifs biologiques et culturels, y compris la résistance de l'hôte et les agents de lutte biologique. Dans les systèmes agricoles des pays tropicaux, les buts de l'IPM étant d'assurer un environnement sain, signifient la lutte antiparasitaire, exigeant des apports extérieurs moindres dans le système.

Ce rapport examine les moyens permettant d'accroître l'efficacité d'emploi des fonds importants actuellement investis dans la lutte antiparasitaire par les agences internationales de développement, avec une réduction consécutive des pertes par suite des attaques des nuisibles et la réduction des dépenses de pesticides. Les questions clés auxquelles le rapport tente de répondre en ce qui concerne l'utilisation de l'IPM dans les pays en voie de développment sont les suivantes:

- quelles sont les leçons devant être tirées de l'expérience antérieure?
- quelles perspectives sont-elles disponibles et que doit-il être fait à l'avenir afin d'assurer la fourniture de systèmes de lutte plus performants?
- quels mécanismes institutionnels, nouveaux ou améliorés, sont-ils exigés pour assurer la mise à disposition de meilleurs systèmes de lutte antiparasitaire?
- quelles mesures les agences de développement doivent-elles prendre dans leur appui futur de l'IPM afin d'assurer une utilisation plus efficace des ressources?

Il a été étudié lors de l'établissement de ce rapport, l'expérience acquise dans plusieurs pays, les systèmes d'exploitation agricole ainsi que les cultures. Les résultats ont été décevants, en dépit d'investissements significatifs réalisés au cours des 20 dernières années par les gouvernements nationaux et les agences internationales de développement dans des programmes conçus afin de promouvoir l'application de l'IPM. Les principales raisons applicables à ces résultats négatifs ont été les suivants:

- définition insuffisante des problèmes, conduisant à des conceptions médiocres de projets;
- recherches impropres n'élaborant pas des technologies adaptées aux petites exploitations agricoles;
- fragmentation des efforts au sein d'un pays dans lequel la recherche, le développement et la protection des plantes sont fréquemment du ressort de services différents dans les gouvernements;
- politiques gouvernementales impropres, telles que le subventionnement des prix des produits chimiques favorisant l'utilisation des pesticides.

Il y a eu, parmi les agences (aussi bien bilatérales que multilatérales) internationales de développement, quelques tentatives menées à bien de définition d'un problème significatif de nuisibles et de rassembler une 'masse critique' de ressources et d'expertise en vue de favoriser sa solution. Il a néanmoins été observé un certain nombre de succès remportés dans le développement et l'emploi de l'IPM dans les pays tropicaux, en particulier avec le riz dans le Sud Est asiatique, le soja au Brésil et le coton au Zimbabwe. Les caractéristiques communes des projets couronnés de succès ont été les suivantes:

- cible (s) clairement définie (s) et programmes de mise en oeuvre bien focalisés;
- stratégies de lutte antiparasitaire adaptées pour emploi par les petits exploitants agricoles;
- excellents rapports entre la recherche et le développement;
- infrastructure adéquate;
- disponibilité de personnel formé à tous les échelons de la gestion de projet;
- programmes de formation adaptés;
- financement soutenu.

L'objectif de toute initiative internationale dans le domaine de la lutte antiparasitaire doit consister à encourager de la fourniture de programmes de lutte plus efficace s'appuyant sur l'emploi raisonnable de stratégies d'IPM. Il est identifié certaines de ces cibles possibles qui tireraient parti de l'application d'une telle optique. Parmi celles-ci, citons les légumes en Asie et en Amérique centrale et du Sud, le coton en Afrique, le soya en Amérique du Sud et le cacao en Afrique occidentale, au Sud-Est asiatique ainsi qu'en Amérique centrale et du Sud.

Diverses dispositions institutionnelles sont examinées afin de mettre en valeur les options favorisant la mise à disposition de meilleurs programmes d'IPM. Ce sont les suivantes:

Option 1: Mise sur pied d'un consortium donateur pour promouvoir la maise en oeuvre de l'IPM dans les pays en voie de développement.

Option 2: Mise sure pied d'un nouveau Conseil international pour l'IPM, avec représentation des pays clients et également d'experts en matière d'IPM, la FAO, la communauté des doneurs, les organisations non gouvernementales ainsi que le secteur privé. Un conseil international permettrait de mettre en oeuvre ses politiques et de prêter assistance aux programmes nationaux pour définir les besoins et pour étudier des programmes d'IPM plus performants grâce à la création d'un Groupe de ressources d'IPM, disposant d'équipes permanentes basées en Asie, en Afrique et en Amérique latine ainsi que des cadres supérieurs de liaison implantés en Amérique du Nord et en Europe. On estime que le coût annuel s'élève à 2,5 millions de $ US.

Option 3: Similaire à l'Option 2 mais fait intervenir la mise sur pied initiale d'un Groupe de ressources en Asie seulement afin de prêter assistance aux programmes nationaux, sur la base que le prolongement à l'Afrique et à l'Amerique latine dépendra des succès remportés en Asie. Le budget annuel est estimé à 750 000 $ US.

Option 4: Mise sur pied d'un nouveau consortium international pour l'IPM des membres des agences donatrices et des représentants d'organisations gouvernementales nationales et nationales, y compris les pays clients. Les politiques du consortium en matière d'aide apportée aux pays clients pour l'étude, le financement et l'emploi de techniques d'IPM plus performantes sur les cultures importantes seraient mises en oeuvre par le truchement d'un Groupe d'intervention d'IPM. Ce groups se composerait d'un noyau d'environ cinq personnes clés dans les disciplines pertinentes, certaines étant détachées par les agences donatrices. Ce personnel serait installé dans un centre technique pour l'IPM, toutefois il travaillerait principalement avec les responsables régionaux de la protection des plantes de la FAO ainsi qu'avec d'autres organisations nationales et internationales dans les pays bénéficiaires. Le coût annuel est estimé à 1,5-2,0 millions de $ US.

Option 5: Un organisme distinct pour mettre en oeuvre et exécuter (tout autant que faciliter) des programmes d'IPM plus performants au niveau du terrain. Cette option exigerait des dépenses élevées pour sa mise sur pied et serait en compétition avec les organismes existants, la FAO par exemple ainsi que les multiples agences bilatérales participant déjà à la mise en oeuvre des programmes d'IPM en Afrique, en Asie et an Amérique latine.

Etant donné (i), l'ampleur des pertes actuelles dues aux parasites; (ii) les perspectives en matière d'IPM actuellement disponibles pour réduire les frais financiers et écologiques associés à l'emploi des pesticides dans les pays en voie de développement; et (iii) les succès restreints des importants investissements réalisés par les gouvernements nationaux, les agences bilatérales et multilatérales de développement dans les projets de lutte antiparasitaire, il est fortement recommandé qu'il soit exploré de nouvelles optiques afin de s'assurer que de meilleures méthodes de lutte antiparasitaire sont mises à la disposition des exploitants agricoles dans les pays en voie de développement des régions tropicales.

RESUMEN

Las pérdidas globales actuales en la producción agrícola, como resultado de los daños producidos por las plagas, ascienden anualmente a USA$ 300.000 millones. El coste anual aproximado de los pesticidas utilizados en la agricultura se eleva a USA$ 20.000 millones. El coste de los pesticidas para los países en desarrollo representa una importante pérdida de divisas a nivel nacional, además de requerir importantes inversiones por parte del agricultor, a nivel local. Durante 1988, las inversiones de las agencias internacionales de desarollo en proyectos de control de plagas se calculó en un mínimo de USA$ 150 millones.

La gestión integrada de plagas (GIP) es la estrategia generalmente recomendada—aunque menos generalmente utilizada—para la reducción de los daños producidos por las plagas, mediante una cuidadosa integración de deversas técnicas de control de plagas. Como realidad práctica, la GIP podría definirse como 'la mejor combinación de tácticas de control por parte del agricultor, en relación con el rendimiento, beneficios y alternativas de seguridad'. Su objetivo consiste en la reducción del empleo de controles químicos y en el máximo aprovechamiento posible de componentes biológicos y culturales, incluyendo la resistencia de las plantas huésped y agentes biológicos de control. En los sistemas agrícolas tropicales, la GIP tiene como objetivo la provisión de medios ambientalmente viables de control de plagas, que requieran un menor número de aplicaciones externas al sistema.

En este informe, se examinan distintos métodos para incrementar la eficiencia en el empleo de los considerables fondos que las agencias internacionales de desarrollo están invirtiendo en el control de las plagas, con una reducción consiguiente en las pérdidas debidas a los ataques de las mismas y una menor inversión en pesticidas. Los interrogantes clave a los que se trata de dar solución, en relación con el empleo de la GIP en los países en desarrollo, son:

- ¿Cuáles son las lecciones a aprender de la experiencia pasada?
- ¿Cuáles son las oportunidades disponibles y qué medidas deberían adoptarse en el futuro para conseguir una mejor aplicación de los sistemas de gestión de plagas?
- ¿Cuáles son los nuevos o mejorados mecanismos institucionales requeridos para conseguir la aplicación de sistemas más apropiados de gestión de plagas?
- ¿Qué medidas deberían adoptar las agencias internacionales de desarrollo en su futuro apoyo a la GIP, a fin de conseguir un empleo más eficiente de los recursos?

Durante la preparación de este informe, se ilevó a cabo un examen de la experiencia obtenida en distintos países y con distintos cultivos y sistemas agrícolas. A pesar de las importantes inversiones realizados por los gobiernos nacionales y por las agencias internacionales de desarrollo en programas diseñados para promover la aplicación de la GIP en los Trópicos, los resultados obtenidos en los últimos 20 años han sido desalentadores. Valga citar como importantes razones de este fracaso:

- una definición inadecuada de los problemas, que ha resultado en un diseño deficiente de los proyectos;
- investigación inadecuada, que no ha sabido diseñar tecnologías apropiadas para el pequeño agricultor;
- fragmentación de los esfuerzos dentro de un país, en donde los sectores de la investigación, extensión agraria y protección de las plantas caen, a menudo, bajo la responsabilidad de distintos departamentos gubernamentales;
- políticas gubernamentales inadecuadas, tales como subsidios a los precios de los productos químicos, que contribuyen a fomentar el empleo de los pesticidas.

Entre las agencias internacionales de desarrollo (tanto bilaterales como multilaterales) ha sido reducido el número de intentos satisfactorios de definir un problema importante de plagas y reunir una ''masa crítica'' de recursos y conocimientos técnicos que contribuyan a su solución. Esto no obstante, se han conseguido diversos éxitos en el desarrollo y empleo de la GIP en los Trópicos, particularmente por cuanto respecta al arroz en la región sudoriental de Asia, la soja en Brasil y el algodón en Zimbabwe. Entre las características comunes a proyectos satisfactorios valga citar:

- objetivo(s) claramente definido(s) y programas de aplicación bien orientados;
- estrategias de control de plagas apropiadas para uso por pequeños agricultores;
- buenos lazos entre los sectores de la investigación y de la extensión agraria;
- una infraestructura adecuada;
- disponibilidad de personal capacitado a todos los niveles de la gestión del proyecto;
- programas apropiados de capacitación;
- fondos sostenidos.

El objetivo de toda iniciativa internacional sobre gestión de plagas debería ser el fomento de la aplicación de programas más eficaces de control de plagas, basados en un empleo sensato de estrategias GIP. El informe identifica algunos de los posibles productos, que podrían beneficiarse de la aplicación de esta política. Valga citar, entre ellos, las verduras en Asia y regiones de Centroamérica y Sudamérica; el algodón en Africa; la soja en Sudamérica; y el cacao en el Africa Occidental, Sureste Asiático, Centroamérica y Sudamérica.

Con objeto de poner de relieve las opciones a favor de una mejor aplicación de los programas GIP, este informe examina distintas medidas institucioinales, a saber:

Opción 1: Establecimiento de un consorcio donante para promover la aplicación de la GIP en los países en desarrollo.

Opción 2: Establecimiento de un nuevo Consejo Internacional para la GIP, que cuente con representación de los países cliente, de expertos en GIP, FAO, comunidad donante, ONGs y sector privado. El Consejo Internacional Ilevería a la práctica su programática y prestaría asistencia a los programas nacionales en la definición de necesidades y diseño de programas GIP más efectivos, mediante la creación de un Grupo de Recursos GIP, con equipos permanentemente basados en Asia, Africa y Latinoamérica, así como personal de coordinación en Norteamérica y Europa. Su coste anual aproximado sería de USA$ 2,5 millones.

Opción 3: Similar a la opción 2, pero con el establecimiento inicial de un Grupo de Recursos únicamente en Asia, para prestar asistencia a los programas nacionales, sobre la base de que la expansión en Africa y Latinoamérica estaría supeditada al éxito en Asia. Su presupuesto anual aproximado sería de USA$ 750.000.

Opción 4: Establecimiento de un nuevo Consorcio Internacional para GIP con miembros de las agencias donantes y representantes de organizaciones gubernamentales nacionales e internacionales, incluyendo los países cliente. La aplicación de los programas del consorcio por cuanto a la prestación de asistencia a los países cliente en el diseño, financiación y aplicación de una GIP más eficaz en cultivos importantes se realizaría por intermedio de un Grupo de Acción de GIP. El Grupo de Acción comprendería un núcleo de cinco personas clave especializadas en disciplinas apropiadas, procediendo algunas de ellas de las agencias donantes. Si bien el Grupo de Acción estaría basado en un centro de excelencia de la GIP, su labor se realizaría, en gran parte, con personal regional de protección de plantas de la FAO y con otras organizaciones nacionales e internacionales de los países receptores. Su coste anual se calcula en unos USA$ 1,5-2,0 millones.

Opción 5: Una institución separada cuya misión fuera la aplicación y ejecución (así como la facilitación) de programas GIP más eficases sobre el terreno. Su establecimiento Ilevaría consigo gastos importantes. Pot otra parte, competiría con instituciones ya en existencia, tales como la FAO y las muchas agencias bilaterales que están trabajando en la aplicación de programas GIP en Africa, Asia y Latinoamérica.

Teniendo en cuenta (i) la magnitud de las pérdidas actuales debidas a las plagas; (ii) las oportunidades de GIP actualmente disponibles para reducir los costes financieros y ambientales asociados con el empleo de los pesticidas en los países en desarrollo; y (ii) el limitado éxito de las vastas inversiones realizadas por los gobiernos nacionales y por las agencias bilaterales y multilaterales de desarrollo en proyectos de gestión de plagas, se recomienda encarecidamente la exploración de nuevos planteamientos para conseguir que los agricultores de los países en desarrollo de los Trópicos puedan tener a su disposición métodos más apropiados de gestión de plagas.

Introduction

Integrated pest management (IPM) comprises strategies aimed at minimizing pest damage through the careful integration of available pest control technologies. It gives priority to non-chemical control components such as host-plant resistance and biological and cultural controls, only using chemical controls when alternatives are clearly unlikely to afford sufficient protection. In tropical agricultural systems, where pesticides are increasingly expensive and pose risks to farmers and consumers, reduced use of pesticides through IPM has many economic and social as well as environmental advantages. Reduced use of chemicals implies reduced cash and other capital inputs into production systems, and for this reason IPM approaches tend to be more sustainable in small-scale agricultural systems. At the same time, IPM strategies minimize environmental damage and health risks. However, in spite of the many proven advantages of IPM, and the demonstrable need for the benefits it offers, its implementation, particularly in developing countries, has been disappointingly slow.

This report discusses the many constraints, political as well as technical, that have affected the adoption of IPM. It emphasizes the need for a realistic approach to future activities, in particular the need to define problems before adopting preconceived notions as to likely solutions. Existing knowledge and relevant organizations are discussed in the light of such an objective approach, as are case histories of past and current IPM projects. Finally there is a discussion of possible modifications to existing practices and of new arrangements that would facilitate the adoption of IPM in appropriate cropping systems in developing countries.

BACKGROUND

The present study arose at a plant protection seminar sponsored by CAB International (CABI) at the Institute of Biological Control (IIBC), Silwood Park, United Kingdom in April 1989. The rationale for the proposed study was discussed further at a meeting in Canberra, Australia in May 1989. The meeting was attended by representatives of several bilateral development assistance agencies, FAO, CABI, the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR), and the CGIAR Secretariat. The participants at the Canberra meeting considered that the proposed study would complement the current review of plant protection activities commissioned by TAC. Given TAC's commitments, it was not in a position itself to undertake a more comprehensive study on IPM. The TAC representatives noted that the study would be a welcome complementary effort, especially if completed in time for TAC to benefit from the findings before making final recommendations to the CGIAR on future activities in plant protection. To meet this deadline an interim study report was given to TAC by 31 December 1989.

The study was directed by a Task Force, whose core group were representatives of interested development agencies who were supporting the study financially. A list of Task Force members is attached (*see* Appendix 2). The Task Force commissioned consultants to prepare initial reports as a basis for its discussions.

The terms of reference for the study were to:

- review past experience in pest management in the developing countries;
- identify socio-economic, institutional and technical constraints to the successful application of pest management to food, cash and export crops;
- identify criteria for successful pest management programmes;
- review the role of international development agencies in the implementation of pest management programmes, and identify options for better integrating these efforts; and
- identify ways to support the wider use of effective pest management in developing countries, and the institutional arrangements that would facilitate such wider use.

These terms of reference highlighted the more effective implementation of IPM and associated research in developing countries, rather than strategic or basic research on IPM. They emphasized activities relevant to IPM implementation by the farmer, through national and regional organizations.

DEFINITIONS AND OBJECTIVES OF IPM

IPM is not a new concept, but has gained widespread scientific recognition in the past two decades; however it has yet to enjoy broad implementation. While the biological basis of IPM is now well established, political support for IPM approaches is still weak. The term is synonymous with integrated pest control (IPC), which has been defined by FAO as

> a pest management system that, in the context of associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains pest populations at levels below those causing economic injury. It is not simply the juxtaposition or superimposition of two control techniques but the integration of all suitable management techniques with the natural regulating and limiting elements of the environment.

IPM implies the improved use of chemical inputs, natural environment controls and cultivation practices, including traditional controls which farmers have developed through trial and error, often over centuries. IPM is based on the principle that each control method used will influence the potential role of other methods, with pesticides and other chemicals envisaged as last-resort tactics. This integrated approach, giving priority to natural mechanisms while adopting chemical pesticides for strategic interventions, has been the subject of world-wide scientific research and field testing for more than 20 years.

Why has there been so little implementation of IPM? Perhaps the single most important factor has been the overly academic approach adopted by many of its advocates, who support the basic philosophy but have not implemented IPM in actual field programmes. In practice, the outcome of their work has often been unacceptable or unmanageable for the farmer and the local advisory services.

Norton (1987) has argued for an objective approach to research that does not involve preconceived notions of where the solution is likely to lie. The message is that for each particular location, 'we must first define the problem and only then look for appropriate solutions'. This procedure depends on careful examination of the farmer's crop production strategy as well as other social, economic, political, ecological and technological dimensions that could have a bearing on pest control practices in the field. This type of holistic view of IPM is the foundation for FAO's approach in its regional South-East Asian IPM rice programme, for which Kenmore *et al.* (1985) define IPM as "the farmer's best mix of control tactics in comparison with yields, profits and safety of alternatives". This view is in full accord with the present Task Force's objectives, and with the philosophy underlying this report.

ADVANTAGES OF THE IPM APPROACH

IPM was initially conceived as a response to world-wide pest problems created by excessive use of synthetic pesticides and increasing rates of pest resistance to those chemicals. Much IPM research work has therefore focused on the biological basis of pest management. More recently, IPM has taken on important economic and social overtones. The lower costs of IPM, as compared with conventional pest control, are of economic significance both at the national level, where many of the poorest countries spend tens of millions of dollars to subsidize pesticide use, and at the farm household level, where scarce funds are spent on pesticide applications that may give little or no benefit. At the same time, governments, farmers and consumers are becoming increasingly alarmed at the health implications of pesticide use. The opportunity cost of not adopting IPM strategies is high, yet this is not adequately appreciated by the agricultural research community and has yet to be addressed by national agricultural policies. Although this situation differs little in developing and industrialized countries, the economic costs are worse for the poorer developing countries whose economies are dominated by agriculture.

While the economic implications of IPM are still awaiting their rightful place in research and policy agendas, a new perspective of IPM is emerging as an environmental strategy. The potential which

IPM offers for reducing pesticide use is of profound environmental significance for directly improving water and air quality. The environmental benefits of IPM are also causing a transformation of its agricultural role; it is now being viewed as a central component of the new concern about environmentally sustainable agriculture. The environmental benefits of reduced chemical loads, coupled with new thinking about plant-pest interactions as complex, dynamic systems, is helping put IPM at the forefront not only of agricultural development plans, but also of national and international environmental plans.

From the perspective of rural development, IPM can play an important role in the process of local (village) self-reliance. Farmers who use a mix of traditional and modern techniques learned through their own experience (with or without outside extension assistance) feel that they 'own' that knowledge and are stimulated to seek greater management control of other production activities such as irrigation, soil conservation, credit and marketing. Extension workers (from either government agencies or non-governmental organizations) can facilitate farmers' sense of empowerment only if they are themselves empowered through their own training. The process of discovering new skills and knowledge is not merely a product of an IPM approach, but is an essential feature of the process by which IPM needs to be implemented at the local level. The development of the technology is part of a process of developing human resources.

At the policy level, the climate of world opinion has never been more conducive to the message of IPM. From the perspectives of agriculture, economics, environment, and perhaps most significantly politics, IPM has an unprecedented role to play. One of the most effective methods for promoting that role will be through broad-based public awareness efforts aimed particularly at government policy-makers, international development agencies, and the research community.

The rationale for IPM implementation includes:

- *Environmental quality.* Pesticides nearly always affect non-target species along with the intended targets, upsetting the local ecological balance. Pesticides may also affect ecosystems far removed from farmers' fields, through movements in ground and surface water, and in air.

- *Economics.* The shadow price of chemicals may be much greater than the nominal price, due to several layers of subsidy (at the levels of both less-developed countries and international development agencies, and through dumping at below-cost prices by manufacturers). When environmental costs are included, the total social cost of pesticides may become higher as a result of improper use. In a more rational world, governments and farmers could not afford not to adopt IPM.

- *Health.* Handling and application of chemicals poses health hazards to the poorest sectors of the population, who obtain menial jobs in the agrochemical production/marketing business, and to poor farmers who know nothing about the hazards, or who do not possess the equipment to use chemicals safely. Moreover, in hot climates the use of protective clothing is often impractical. Pesticide residues in or on food can pose a serious health hazard to consumers.

- *Social criteria.* The addiction of farmers to heavy use of pesticides in conventional agriculture imposes new levels of dependency on the outside world, whether private businesses or government agencies. Community-level initiatives based on local leadership and co-operation are undermined, creating a feedback effect of greater dependence on external authorities to solve local problems.

- *Political criteria.* The stability of agricultural production which IPM makes possible has important benefits for political stability at the national level. In countries where a single crop dominates agriculture, and also where agriculture is the dominant sector of the economy (as in most developing countries), governments can fall if production of the dominant crop is ravaged by pesticide-resistant pests. IPM tends to buffer these effects by maintaining natural controls in the ecosystem.

- *Local knowledge.* IPM builds upon local indigenous farming knowledge, treating traditional cultivation practices as components of location-specific IPM practices. This approach is inherently more efficient than a conventional blueprint approach to pest control, and encourages local experimentation and adoption by farmers, which are essential to long-term agricultural sustainability.

In any particular case, the factors determining the best mix of pest management tactics are not necessarily under the control of the farmer. Some of these exogenous considerations include pre-planting components (such as provision of disease-free seed), and regional regulations such as quarantine, legislation on cropping practices, and regional controls against migratory pests like locusts.

IPM incorporates too many disparate elements to be viewed as a product that can be packaged; rather, it needs to be seen as a process of learning and problem solving. Successful IPM implementation is crucially dependent on understanding problems at the farm, family and community levels, as well as at the level of the many agricultural advisers, governmental and otherwise.

FACTORS INFLUENCING SUCCESSFUL IPM PROGRAMME DESIGN

The IPM decision-making context

One of the major causes of unsuccessful IPM implementation in developing countries is research that has been too science-based, sometimes with unduly ambitious goals or with ill-defined objectives that may bear little relationship to what is practicable. One failure in particular has been a lack of appreciation by pest management specialists that IPM is only part of the overall crop production system, and that pest control options can be severely constrained by other crop production priorities perceived by the farmer. Moreover many IPM specialists, in failing to recognize the need to integrate their research with that of other specialists, fail to practise what they preach.

The agro-ecosystem approach

IPM tactics cannot be formulated for pests of a particular crop in isolation from the cropping system, or more broadly the agro-ecosystem, of which the crop is a part. The priority farmers give to a a particular crop or pest problem is linked to all other crops in the cropping system. The structure and composition of the chosen crop community in time and space can have a major influence on pest incidence and on damage to any particular crop species. Wild plants can also be an important part of the agro-ecosystem—as weeds, or indirectly as alternative hosts of pests or of beneficial organisms.

IPM practices must recognize the significance of the farmer's overall cropping system, in terms of both constraints and opportunities for pest control. In the past too much emphasis has been placed on attempts to transfer technologies of high-yielding, temperate agriculture to the tropics to replace and/or transform traditional farming systems, without regard for the important qualities of what were then assumed to be inefficient practices: for example, monoculture production was regarded as preferable to intercropping. Research, including pest management, which is directed at improving rather than replacing traditional cropping practices is undoubtedly the correct approach for helping to improve both yield and stability of production in such delicate systems.

New technology for relatively resource-poor farmers must therefore be developed with great sensitivity to the severe constraints experienced by the farmer. Failure to do this has been responsible for some past programmes being costly failures. Such misguided work has also been detrimental to the image of IPM and has consequently been a serious setback to further funding for work in those farming systems which, perhaps more than any other, require external support because they occur where poverty and starvation are worst.

The drive towards increased yields has usually involved narrowing the genetic base of a crop, planting large areas of monoculture, and increasing the intensity of sequential cropping. Such practices have almost invariably weakened the sustainability and stability of the agro-ecosystem, affecting pest incidence and available pest management options. The outcome has been greater dependence on pesticides, with a deleterious effect on natural enemies, in some cases leading to new pest attacks.

Such problems have been compounded by induced resistance of target pests, which has led to a cycle of heavier application and further impact on beneficial non-target species.

Two examples illustrate the dilemma. Firstly, the necessary intensification of rice production, with up to three crops per year in well irrigated areas, has made some pests worse and has also created new pests. Yet forecasts by the International Rice Research Institute (IRRI) foresee the need to double South-East Asian rice production in the next 20 years. Secondly, in many parts of Africa the main response to increasing food needs has been to bring more land into production. This has involved erosion of some traditional farming systems whereby cultivated land is returned to 'bush fallow' for up to about seven years, a practice which not only re-establishes soil fertility, but also controls weeds and soil pests. Such bush fallow periods are now being shortened or even disregarded as the critical transition to permanent agriculture takes place in many areas. The increasing intensification of land use practices—manuring, fertilizers, pesticides and hand-weeding—puts a premium on pest control techniques and on the need to devise alternative IPM methods.

Farmers' decision models for IPM implementation

Fundamental to understanding how pest management practices evolve at the farm level are the factors underlying farmers' decision-making on pest management technology. A farmer-based approach may seem all too obvious but there has been, and continues to be, considerable waste of time, money and effort on so-called applicable research. Field studies as discussed by Chambers *et al.* (1989) highlight the need for a farmer-orientated approach. Some projects have already demonstrated its value, e.g. on rice IPM in parts of South-East Asia, cotton IPM in Zimbabwe, and soybean in Brazil (*see Current Status of Pest Management Activities,* p.16).

In a few countries, the government assumes full responsibility for controlling certain pests, notably migrant species. However, in most cases the control of weed, disease, insect and other animal pest problems is the responsibility of the farmer.

Figure 1 shows components of a decision-making model for farmer pest management. The model comprises the following:

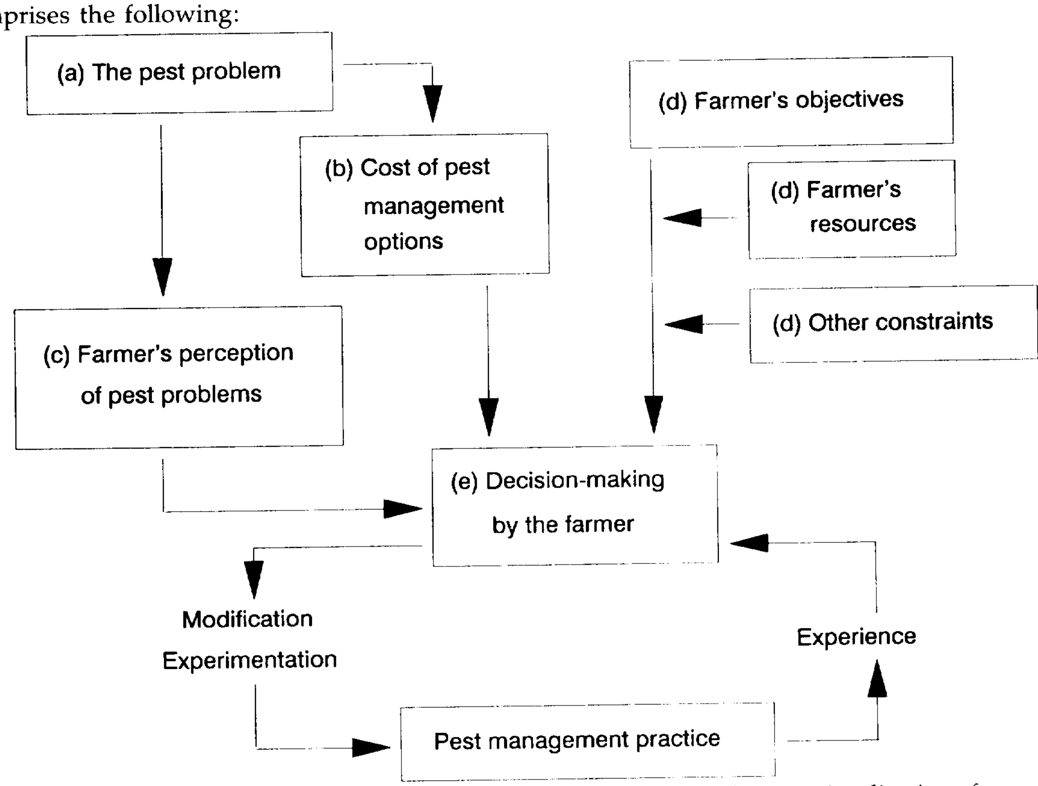

Figure 1 Farmer decision-making on pest management technology adoption: implications for research

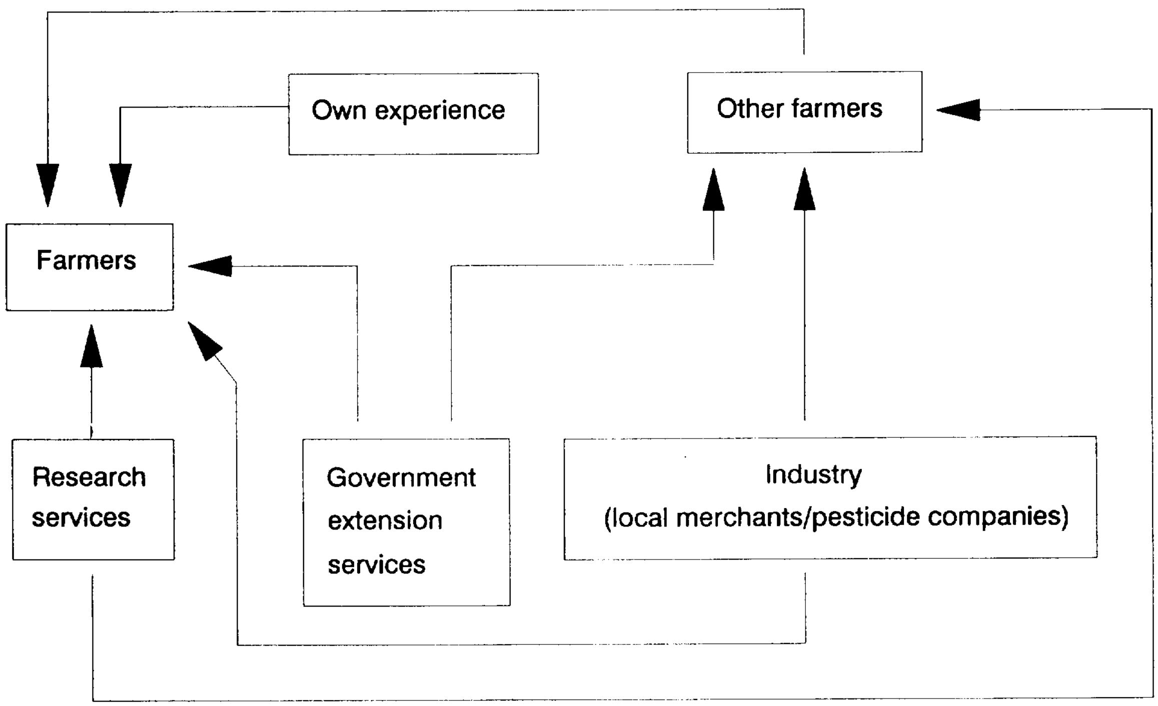

Figure 2 Farmers' sources of pest management information

(a) The pest problem. The pest, or more often the complex of pests, the crops or combination of crops in which the pests are a problem and the stage at which the crop is attacked all impose limitations on the farmer's technical option.

(b) Pest management options and their cost. These arise from indigenous technical knowledge or from research output. The sources are variously the farmers themselves, other farmers, government extension services, commercial pest control companies, or researchers (*see* Figure 2).

(c) Farmers' perceptions of pest problems. A major distinction is drawn here between the views of the farmer and those of the researcher. One of the most common causes of low uptake by farmers has been inadequate consultation with farmers at the outset, and the erroneous assumption that their perceptions will coincide with the researcher's.

(d) Farmers' circumstances (objectives, resources and other constraints). Farmers' perceptions of pest threats and, more importantly, their reactions will be determined by the farming system within which they operate. Factors such as the value of the crop in relation to other farm enterprises, as well as farmers' expectations of future weather conditions or pest (particularly insect) attacks, will be weighed against their resources, their vulnerability, and their attitudes to risk. Farmers' circumstances are constantly changing, so that a pattern of rational behaviour today may not be the one they are likely to follow tomorrow. The farmer's objectives include meeting the basic subsistence requirements of his/her family, as well as an open set of non-economic or 'social' objectives which determine a larger part of so-called 'economic' behaviour in any society. The resources available to meet these objectives, however, are not all within the farmer's control. Many are provided through government services (e.g. extension), the private sector (local markets), the community (artisans and other specialists) or local organizations (village administrations, non-governmental organizations, etc.). Factors under the farmer's direct control - land, labour, capital and, not least, knowledge - interact with the above-mentioned exogenous factors and the degree of reliability the farmer is able to place on them.

(e) Decision-making by the farmer. As well as taking account of all the above factors, the farmer also makes decisions about pest management technologies. This involves dynamic technology selection, modification and experimentation. The experience generated is fed back into the decision-making process and influences subsequent technology adoption. Costs are always involved in decision-making because of the need to gather and analyse information. Farmers' willingness to bear these costs is a function not only of their 'expenses' (the difficulty and time requirements of the IPM technology) but most importantly, the 'ownership' of that technology. When farmers are actively involved in developing IPM procedures, they become owners of that technology.

National policies on IPM

National policies for supporting IPM objectives are of fundamental importance. Farmers will tend to use a mix of pest control measures which they perceive as being economically optimal. Their concern is not yield *per se*, nor the quality of the off-farm environment. While they may be much concerned with the sustainability of their own crop production, farmers are often unaware of possible long-term effects of pesticides on the agro-ecosystem or on the health of their own families.

In terms of pest management, perhaps the most conspicuous factor in the contradictions between the economic signals received by the farmer and the objective of environmental sustainability (which in the long run is equivalent to agricultural sustainability) is pesticide subsidies. Pricing interventions to subsidize the costs of agricultural pesticides are widely used by governments to ensure farmers' short-term agricultural productivity and profitability. The financial cost to governments may be enormous, and in virtually all cases it is highly questionable whether this represents the most efficient allocation of resources, given the IPM alternative.

A study of pesticide subsidies (Repetto, 1985) in nine developing countries (three each in Africa, Asia and Latin America) has shown that pesticide subsidy rates varied from 19% (China) to 89% (Senegal). While in some cases pesticide subsidies may be necessary to protect national food supplies (by making pest control accessible to poor farmers), such subsidies also distort pest management practices. National policies to provide pesticides at favourable prices directly affect the farmer's pesticide-use patterns. Farmers select the least-cost mix of pesticides and will use the amounts they believe are warranted given their cost, anticipated production benefits, and the perceived risks of not using adequate amounts. The result in many developing countries has been an over-reliance on chemical pest control and a drastic overuse of chemical pesticides in crops such as rice, cotton and vegetables. Farmers who cultivate vegetables invest heavily in seeds, fertilizer, water and labour in the anticipation of high returns. Cheap pesticides are well worth the extra cost, in the farmer's view, as a means of insuring his/her investment.

The results of pesticide overuse are well known, but bear repeating: pest resistance requiring ever higher doses and new chemicals; depletion of natural enemies that could otherwise hold some pest populations in check; depletion of micro-organisms in the soil which contribute to proper soil structure and fertility; a chain of effects beyond the locality where the chemicals are applied, including threats to wildlife and pollution of drinking water; and direct and indirect health hazards related to transport, storage, use and disposal of pesticides. Added to this are health hazards from pesticide residues in foods sent to market (which typically receive higher doses than food consumed by the farmer), and the fact that some of the cheapest pesticides are among the most environmentally persistent or acutely toxic. When these environmental and health 'costs' are included, the real cost to society of pesticide subsidies is crippling. Subsidies therefore represent one important element of national policies which can undermine the implementation of IPM.

Are governments less rational than farmers? In fact, government policy is a response to influences not unlike those affecting the farmer (*see* Figure 1), as outlined in Figure 3 where 'government' is substituted for 'farmer' and 'policies' for 'practice'.

The information that feeds into national pest management policies is also analogous to the farmer model, although the informational sources are rather different. Instead of 'information' the term 'influence' more accurately describes the dynamics underlying national policies. The model is depicted in Figure 4, which is adapted from Figure 2.

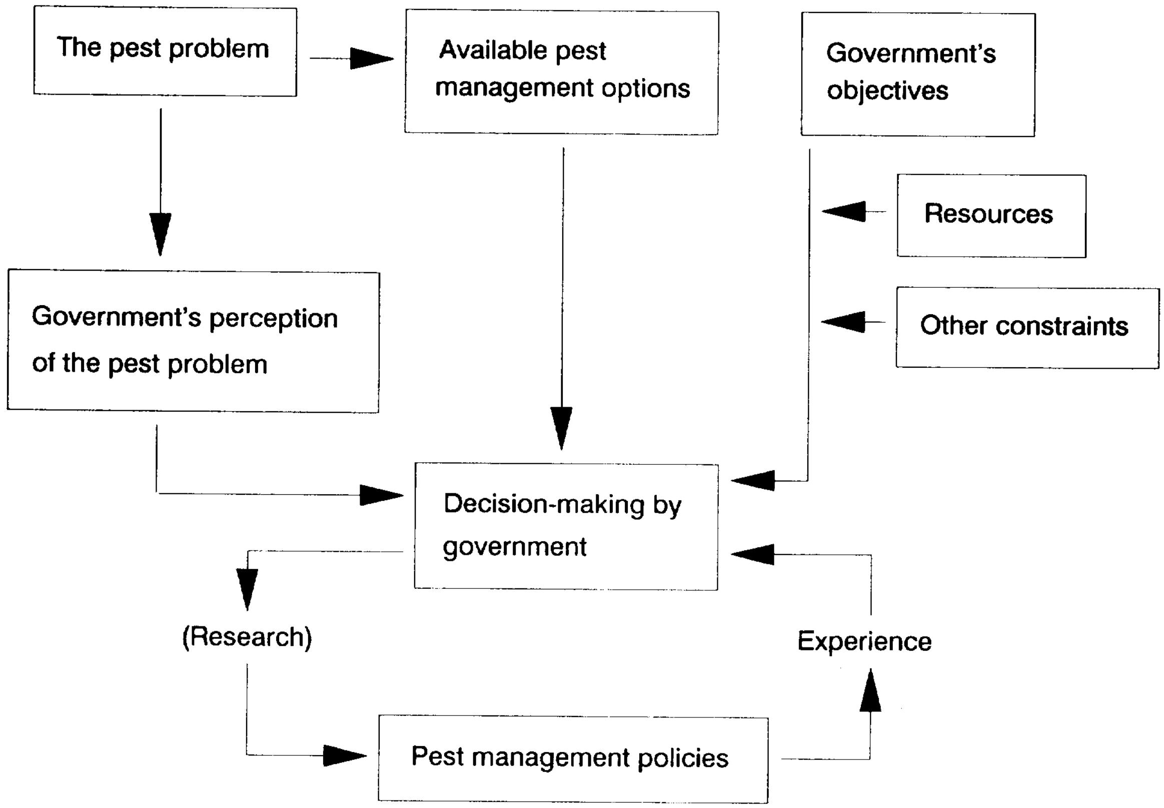

Figure 3 Government decision-making on pest management selection

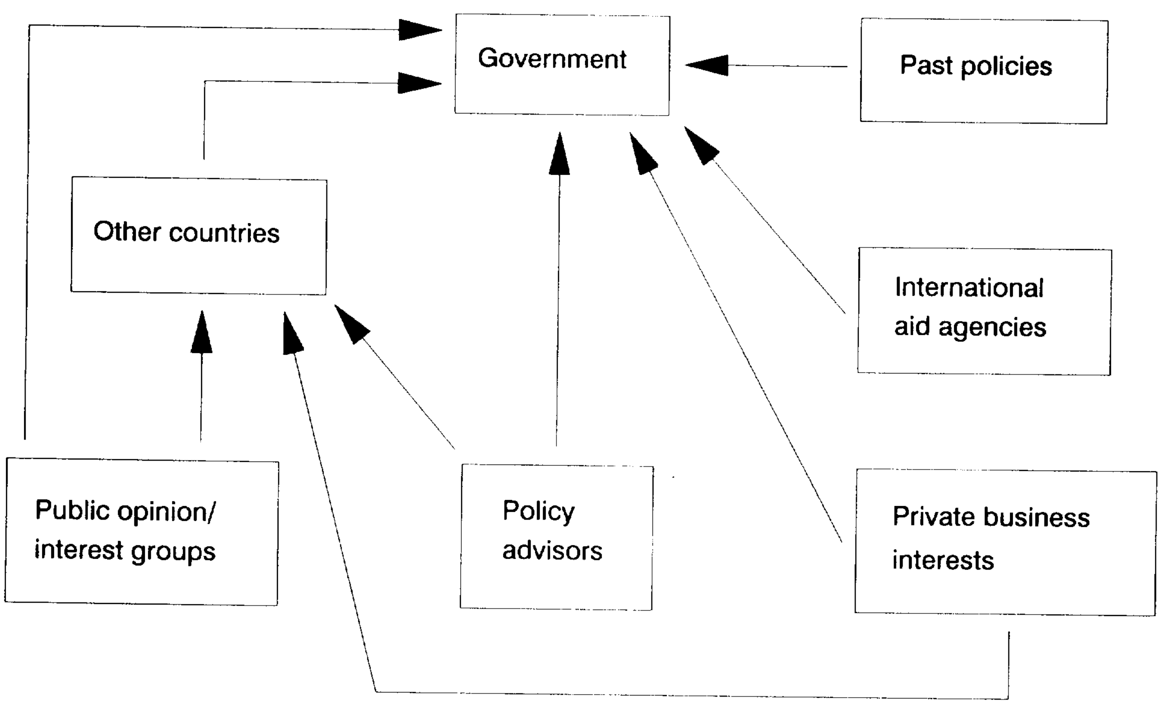

Figure 4 Government channels of information and influence

A significant feature of the influences working on national policy is that, just as national pesticide subsidies affect the economic decision-making of farmers, so the nature of international aid affects government policies.

International aid policy

Internationally-funded agricultural programmes and projects impose conditions on national policies (*see* Figure 4), which are in turn determined by internal priorities and policy guidelines within international development agencies (whether bilateral or multilateral). Some agencies (such as USAID) apply environmental guidelines on which pesticides can be used and how they are to be regulated. International development agencies, however, frequently include subsidies for purchasing particular chemicals and equipment, or outright grants with much less stringent environmental guidelines.

A decision-making model for international development programmes, and the policies that drive such programmes, can also be depicted using the same general categories as in the preceding figures. Pest management decisions are made in the context of the development agency's objectives, as well as its perception of the pest problems. Thus with locusts in Africa, the perceived urgency of the problem has outweighed the IPM objectives of many development agencies, and large quantities of potent chemicals have been used as an emergency measure.

As with national and farmer levels, an international development agency is exposed to diverse influences. The policies of other agencies are a factor, but more important are the public opinion in the donor country; the policy advice which the agency receives from outside experts; and, not least, the influence of private corporations which is often felt through political channels within the donor government.

The costs to developing countries of not bringing their policies into line with IPM objectives are greater than the costs to industrialized countries in terms of both environmental dangers and economic costs, due to a lack of regulation, greater or potentially greater pest problems, and greater reliance on agriculture in the developing world. The IPM model may present problems as well as advantages, but it cannot evolve without supportive national and international policies.

Pesticide use in relation to IPM

The IPM concept was stimulated by the deleterious effects of over-dependence on pesticides. This section briefly outlines differing pesticide usages in relation to pest management opportunities.

No pesticide use. Pest control, if practised at all, is based on indigenous methods such as cultural controls. Pest damage may or may not warrant additional protection, perhaps including pesticides. Many rainfed agro-ecosystems in the developing world, especially subsistence farming, are in this category.

Pesticide use in balance. Pesticide use is at an apparently 'acceptable' level. It may be used in conjunction with other non-pesticide controls, or different pesticides may be rotated to discourage the build-up of resistance. In Nepal, for example, farmers are spraying vegetable crops with insecticides once or twice depending on the level of infestation. This situation has prevailed for at least five years and therefore appears to be in balance.

Pesticide use moving out of balance into crisis. A regime characterized by the increasing use of pesticides, as for example in the Pakistan Punjab where the number of insecticide sprays on cotton is increasing. This situation may be reversible under circumstances where pesticides become uneconomic. For example, in parts of the Sind (Pakistan), when there is insufficient irrigation water, farmers stop spraying, because to continue would be economically unsound.

Pesticide use in crisis. Well established pesticide resistance is combated by increased pesticide use leading to enhanced resistance, destruction of natural controls and development of new pests, as well as serious environmental pollution. Several examples have been documented, especially on cotton and vegetables.

Current Status of Pest Management Activities

TECHNICAL/SOCIO-ECONOMIC ACTIVITIES

Many attempts have been made to implement IPM projects in developing countries, either directly or as components of larger development aid projects. There have been few successes and many failures. While rice is considered the 'object lesson' for successful IPM implementation in the developing world, it must be recognized that this success has so far been limited to a very small population (fewer than 5% of Asian rice farmers), only to irrigated rice in southern and South-East Asia, and using only a small set of tools. Even with rice, much remains to be done in terms of integrating modern techniques with traditional practices in the use of varieties, cultural practices, biological control and pesticides. Because of the importance of this crop to global food security, rice IPM requires further donor support for the development of integrated, 'farmer-friendly' control techniques, and to extend IPM both within Asia and to other rice ecosystems.

After rice, cotton and vegetables are probably the crops that require most urgent attention because of insecticide misuse. This is especially serious with vegetables, where IPM is not practised significantly, and with cotton, where (with one or two notable exceptions, especially Zimbabwe) IPM has been relatively unsuccessful. One crop in which IPM has been implemented, however, is soybean in Brazil, and this provides some valuable guidelines for IPM on other major crops.

Methodology

A questionnaire (*see* Appendix 4) was devised in order to gather information on IPM implementation from scientists who have experience of field problems. Some 30 questionnaires were returned in time for a meeting of the Study Team in Washington DC in November 1989. The information gathered provided a preliminary assessment of IPM opportunities, though it must be stressed that much more detail is needed before reliable decisions can be made on feasibility.

Completed questionnaires and their authors are listed in Appendix 5, and all questionnaires have been retained for future reference. The main conclusions are summarized below, and a detailed analysis (Iles, 1990) and a summary (Iles and Sweetmore, 1991) are available on request from M. Iles (address in Appendix 2).

Examination of selected crops and cropping systems

Rice

A detailed review of tropical rice has been made by Teng (1990 - available from M. Iles). The following is a summary of the review and includes inputs from several questionnaire respondents.

Experience in tropical rice clearly demonstrates that the IPM concept can be selectively applied to meet both the on-farm and the national plant protection needs of developing countries. The lessons learnt from the rice case study are that, given a conducive policy environment, and support for on-farm activities, farmers can be taught relatively simple techniques to rationalize insecticide use and conserve natural enemies. In addition, it has been demonstrated that with Asian irrigated rice, IPM can maintain yields and profits and reduce insecticide use (*see* Iles and Sweetmore, 1990; Teng, 1990).

The rice system. Rice is the staple food of at least half the world's population and is grown in approximately 148 million ha of land globally. The world's major rice-growing region is Asia (132.6 million ha), followed by South America (6.8 million ha), Africa (5.0 million ha), and North and Central America (1.9 million ha). The Asian rice area is therefore approximately 89.6% of the global total, in a region which supports about 60% of the world's population.

Important rice-growing countries are India (42.8 million ha, 28.9% of world total), China (34.3 million ha, 23.2%), Bangladesh (10.5 million ha, 7.1%), Indonesia (9.9 million ha, 6.6%), Thailand (9.7 million ha, 6.6%), Vietnam (5.6 million ha, 3.8%), Burma (4.7 million ha, 3.2%) and the Philippines (3.3 million ha, 2.2%). In the Americas, Brazil is the biggest producer with 5.4 million ha (3.6% of world total), followed by the United States with 1.1 million ha (0.7%). The only major rice-growing country in Africa is Madagascar, with 1.2 million ha (0.8%). Asia has approximately twice as many rice holdings as the rest of the world combined (approximately 10 million ha against 5 million ha, respectively).

Rice is grown in four to five major rice ecosystems, namely irrigated (about 52.8% of world rice area), rainfed lowland (about 22.6% of world area), upland rice (about 13.0% of world area), deep-water rice (8.2% of world area) and tidal wetlands (about 3.4% of world rice area). Of the two biggest rice-growing countries, India has predominantly rainfed ecosystems (over 60%) while China has mainly irrigated rice (over 90% of area).

Between 1965 and 1985, there was a large increase in the percentage of modern high-yielding varieties grown in most rice-growing countries of Asia at a time when the rice-growing area was increasing. China has the highest percentage (95%) of its area planted to high-yielding varieties, followed by the Philippines (85%), Indonesia (82%), India (54%) and Burma (49%). Most high-yielding varieties are grown with high inputs of fertilizer, pesticides and irrigation. In the 1970s this mixture of technologies resulted in spectacular pest outbreaks in several Asian countries, and led to the development of IPM programmes in these and other countries.

Rice pests. Approximately 30 species of insect, 16 disease strains and 15 weed species are considered economically important. In irrigated rice ecosystems, brown plant hopper (BPH), leaf-folder, stemborer, and green leafhopper (GLH, as a vector of rice tungro virus) are important. The BPH is probably the single most important insect problem in rice today. Important diseases are rice tungro virus (RTV), sheath blight, bacterial blight and blast (on susceptible varieties). Weeds and rodents cause further substantial losses in certain areas.

In upland rice, important insects in Asia include grasshoppers, armyworms, leaf-folders, seedling maggots and rice bugs, together with soil insects such as ants, termites and white grubs. Most upland rice diseases are fungal; they include blast, brown spot, leaf scald, sheath blight, sheath rot, narrow brown spot and eyespot. Bacterial and viral diseases are uncommon. Blast is probably the most devastating disease throughout the upland areas of Latin America, Africa and Asia, with losses of 50-80% having been reported.

Deep-water rice in southern and South-East Asia appears to be particularly prone to infestation by the *Ufra* nematode and by bacterial blight. Important, ubiquitous weeds of rice are *Cyperus* and *Scirpus* spp. (Cyperaceae), annual grasses (especially *Echinochloa* and wild *Oryza* spp.) and some broad-leaved weeds.

Present initiatives. A major force that has shaped the evolution of IPM thinking and its field implementation is the FAO Inter-Country Programme for Integrated Pest Control in Rice in southern and South-East Asia (Teng, 1990). This programme remains one of the best examples of IPM implementation in a tropical developing country. It involved purposeful, direct efforts to change farmer practices, in contrast to some more indirect routes of IPM technology diffusion in many industrialized, temperate environments. The programme itself has evolved into its present trans-national form from a relatively small project supported by Australia in the late 1970s, following the large-scale pest outbreaks in several South-East Asian countries mentioned above. The first phase of the FAO programme (1980-86) focused on developing and testing the technical aspects of the IPM concept in its seven participating countries - Bangladesh, India, Indonesia, Malaysia, Philippines, Sri Lanka and Thailand. More recently, the project has been directed towards enhancing farmers' adoption of IPM. The programme is supported by Australia, the Netherlands and the Arab Gulf Fund. One significant accomplishment of the programme has been to cause policy changes within several governments, in the form of official support of IPM as the means for national plant protection in the Philippines, Indonesia, India, Sri Lanka and Malaysia. There is no other programme which matches the scope or field-level orientation of the FAO integrated pest control project; it is the only active regional IPM project in the tropics, despite a strong orientation toward the concept. In Africa and the Americas, extension on rice IPM is generally not well developed. There is no analogous programme on rice IPM research, although several international centres (IRRI, WARDA, CIAT) and many national centres (e.g. in India, Thailand, Nigeria) are actively engaged in research on IPM components.

The FAO regional programme has had an impact only on irrigated rice farming in Asia. There is a significant area of upland and deep-water/tidal wetland rice in Asia, Africa and South America in which IPM has not yet been tested.

Plant protection practices available to rice farmers. It is difficult to assess how widespread and effective are the different methods of plant protection under different conditions, as little reliable data exist throughout the rice-growing world.

Host-plant resistance has been the basis of plant protection for centuries, and has also been the main means of technology transfer, via improved rice seeds, to rice farmers all over the world. IRRI genotypes are probably the most widely grown of any crop, although it is this success which has also led to increased selection pressure on pests and diseases, such as BPH, rice tungro virus and blast, to overcome the resistance. Much of the host-plant resistance in rice is of the 'vertical', single-gene type, and while this has proven useful, frequent insect and disease outbreaks also attest to its weakness when used as the sole method of plant protection. Different degrees of germplasm improvement for pest control are evident in the five rice ecosystems. Irrigated rice has undoubtedly the most sophisticated system of testing and the most knowledge to support this testing.

The use of pesticides for protecting rice has been closely associated with government policy in many of the southern South-East Asian countries, in particular policies which have led to pesticide subsidies. Indonesia, for example, reportedly had an 85% subsidy on pesticides in the early 1980s, costing approximately US$ 150 million per year. Another aspect of widespread pesticide use is its potential impact on human health. In Central Luzon, the ricebowl of the Philippines, there was a 27% increase in insecticide-related mortalities during 1976-82. This phenomenon is by no means restricted to the Philippines and there appears to be general agreement that the magnitude of the problem has been underestimated.

Much of the response to BPH outbreaks in high-yielding varieties has relied on building up natural enemies to allow natural control. Techniques such as need-based application of insecticides, and a fallow period (the 'dirty-bund') all aim at maintaining the balance between different elements of the food web in rice ecosystems. By most accounts, this method of biological control has resulted in substantial savings due to reduced insecticide use and even increased yield. The use of microbial pesticides such as *Bacillus thuringiensis* (Bt) is still relatively limited in rice.

Biological control of plant pathogens does not appear to be practised by rice farmers. Preliminary work using bacteria to control sheath blight appears promising under experimental conditions. Mechanical weeding is practised in many dry-land situations, mostly through between-row tillage. Cultural control such as burning generates enough heat to kill organisms in the topsoil. Paddy-rice farmers have used flooding to drown insects and weeds. The Chinese are known to herd baby ducks and geese through rice paddies where the fowl eat insects and weeds.

Current IPM technologies. IPM component technologies may be divided into three groups: firstly, knowledge technology, in which research findings are translated into information to assist the farmer's decision-making process for pest management; secondly, physical technology, such as equipment, seed, etc.; and thirdly, communication technology which includes ways in which the IPM message is conveyed to farmers. There is relatively little useful pest control technology at present for rice farmers, and most is for insects.

The most useful technologies are diagnostic aids; preservation of natural control; pest assessment and sampling; improved pesticide application technology; improved germplasm with multiple pest resistance; and various cultural methods. Their usefulness in an IPM context has only been demonstrated in Asia and on irrigated rice, although there is reason to believe they are equally applicable to other regions and ecosystems. Technologies with potential include economic thresholds; simple decision aids; germplasm with durable resistance; cultural and biological control; improved problem definition; methods for integrated control of multiple pests; and improved communication technology.

Current impact of IPM. The main impact so far has been on irrigated rice ecosystems in southern and South-East Asia (which holds more than half of the world's population). Irrigated systems in other parts of the world, notably in West Africa and Central/South America, have not seen much benefit from IPM application, and even less impact is evident in other rice ecosystems (upland, rainfed lowland, and deepwater/tidal). IPM has, however, been adopted as the basis for official, national plant protection policy in five southern/South-East Asian nations within three years. The experience in southern/South-East Asia strongly suggests that in developing countries, a conducive policy environment (including official endorsement) is required before IPM implementation, with or without external assistance, can start.

At the national level, investment in IPM programmes can generate a rate of return of 25%, if 20% of the irrigated rice area practises IPM within 20 years of its introduction. It is estimated that 3.7% of farmers of irrigated rice in Asia currently practise IPM (approximately 365 000 farmers out of 10 million). Data from the Philippines further show that in 1986, estimated savings from reduced insecticide use in IPM-trained fields were 21 million pesos, while the total cost of farmer training was 1.5 million pesos, giving an approximate return on investment of 1400%. For an entire country, the returns on investing in IPM become even greater as the percentage adoption increases.

Judging from the current low percentage adoption, it would appear that there is much scope for increased IPM on irrigated rice. One of the measurable benefits to national treasuries in rice-growing countries, as a spin-off from making IPM a national policy, is the reduction or elimination of pesticide subsidies. Indonesia estimated savings to the government of about US$ 50-60 million per year from a reduction in subsidy from 85% to 15% in 1987.

At the micro-level, farmers who practise IPM maintain yield levels while reducing insecticide applications and insecticide levels by about 55%. Nationally, the estimated savings from the relatively small proportion of rice farmers who have been trained in IPM through the FAO regional programme and the Philippines national programme is approximately 33 million pesos annually (US$ 1.58 million). As a technology, IPM has been found to increase yield stability relative to scheduled pesticide application in several countries. IPM farms are generally more profitable than non-IPM farms in Asia. Data also show that 74% of farmers who use simple economic thresholds for insecticide application do so correctly and can obtain a benefit from their use. This statistic is important - detractors of IPM often argue that the techniques associated with IPM are too complicated for most rice farmers.

New initiatives. Improvements to institutional structures, knowledge and technology are needed to accelerate IPM implementation. Diagnosis of pest problems for different situations using systems analysis techniques should be taught to IPM research programme managers. There is also an urgent need for interdisciplinary research into multiple pest thresholds leading to the production of simple, farmer-friendly technology. On-farm testing and technology extrapolation techniques need to be developed. A conducive policy environment will have to be fostered in many countries to encourage adoption of IPM by farmers and decision makers. Complementary networks for research and implementation would further help to focus, co-ordinate and accelerate IPM implementation in rice.

Vegetables

Vegetables are grown in all regions of the developing world and share many common key pest problems. Because product appearance is important in vegetable marketing, there has been significant over-use of pesticides to protect this quality up to and after harvest, resulting in pesticide resistance problems and high levels of pesticide residues in the saleable items.

Consumer awareness of pesticide contamination is increasing rapidly in some countries. Many countries have now realized the need to implement IPM on vegetables. The IPM approach has had little significant impact on plant protection in vegetables because much of the component technology needed is still to be developed. This group of crops therefore offers an opportunity for future donor-supported projects.

Vegetable cropping systems. Vegetables are a diverse group of plants which, for purposes of pest management, are divided by botanical families into solanaceous, cucurbit, and cruciferous. Vegetables are grown in most developing countries for local consumption as cash or subsistence crops, although there are an increasing number of commercial holdings in Latin America and some parts of Asia, growing vegetables for the export market. In general, smallholder vegetable production is on small plots with little or no mechanization, and intensive use of hand labour and agrochemicals. Intense cultivation is practised in tropical vegetable areas such as the Cameron Highlands in Malaysia (50 types of vegetables in 2000 ha) and Baguio in the Philippines. Monoculture is the main mode of planting but rotation is commonly practised, often not for good cultural reasons but in response to anticipated market demands. The intensive use of pesticides on vegetables has led to many examples of pesticide resistance and pest resurgences.

Vegetable pests. In general, most vegetable pest insects are indigenous and often restricted to a country or region. Exotic species are becoming increasingly important because of excessive pesticide use. The diamondback moth, *Plutella xylostella*, is considered one of the most damaging pests on brassicas throughout Asia. Other economically damaging insects are *Agrotis ypsilon*, *Hellula undalis*, *Phyllotreta sinuata*, aphids, agromyzid leaf miners, whiteflies and *Spodoptera litura* on leafy vegetables; and *Aulacophora* spp., *Helicoverpa armigera*, *Dacus* spp., *Earias vitella*, *Maruca testulalis* and *Ophiomyia phaseoli* on fruit and vegetables. Tomato pinworm (*Keifera lycopersicella*) is a key pest in middle America and the Caribbean, and the tomato bud-fruit worm, *Scrobipalpula absoluta*, in South America.

Other serious problems include fungal, bacterial, viral and nematode diseases. Viral diseases on solanaceous crops and cucurbits are a major constraint in the tropics. Fungal diseases include blights caused by *Phytophthora infestans* and *Alternaria solani*, *Septoria* leaf spot, anthracnose on chillies caused by *Colletotrichum* spp., sclerotial diseases of beans and several rusts. Species of bacteria causing substantial losses in crucifers include *Erwinia* and *Xanthomonas*, while bacterial wilt limits where crops such as ginger can be grown. Although weed control is routinely practised by most vegetable growers, weeds are not considered a major problem, probably because they are easier to control than insects and diseases. They can, however, serve as alternative hosts of insects and pathogens.

Present initiatives. There is at present no intercountry, regional or global initiative on vegetable IPM. The Asian Vegetable Research and Development Center (AVRDC) carries out plant protection research and is anticipating increased effort in IPM. Some national programmes also have IPM research efforts on vegetables. In Central America, the CATIE/IPM project and the PanAmerican Agriculture School at Zamorano have made substantial progress with USAID support.

FAO recently completed a pest survey in Latin America and the Caribbean to identify an IPM Action Plan, and has published an IPM manual on vegetables (in English and Spanish) for distribution to technical personnel in the region (FAO, 1990).

Plant protection practices available to farmers. Chemical pesticides provide the most readily available technology for growers, both for preventative and corrective purposes, especially so-called 'pesticide cocktails'. Preventative practices commonly used by farmers include resistant varieties (when available) and cultural practices such as sanitation. Biological pesticides such as *Bacillus thuringiensis* (Bt) are used in some countries, particularly in Asia, while biological control is still very much a research and development activity. Pest control in vegetables is considered by many experts to have reached a crisis phase in some parts of the world: there are serious problems associated with pesticide overuse, and residue levels in vegetable samples for the fresh market have been detected at several hundred times the legal limit.

Current IPM technologies. Only limited IPM component technologies are available to growers. Some surveillance and monitoring is being encouraged in Central American programmes, but very little in Asia. Thresholds for applying pesticides are rarely used, and forecasting systems to reduce the number of applications are still experimental (e.g. in Malaysia). Host-plant resistance is best developed for pathogens. With the exception of limited areas in a few countries (such as China), there is almost no integrated control used at the farm level. Because of the crisis (or near-crisis) situation in many countries, vegetables present an important crop for the development of IPM in the near future.

IPM strategies for tomato insects have been developed and are practised in the Cauca Valley in Colombia, while cultural control is common in many countries; disease-resistant tomato varieties have been released in Brazil. Antagonists to plant pathogens are under study in Argentina and selective use of pesticides is progressing in Chile and Peru.

Current impact of IPM. The impact of IPM on vegetable production has not been measured, as IPM at the farm level is only an emergent technology. For most countries in the developing world, IPM on vegetables is not practised by the majority of farmers.

New initiatives. IPM has great potential for vegetable plant protection in Latin America and Asia. Some *ad hoc* research is being done in national research institutions, international agricultural research centres and regional centres, but this needs to be co-ordinated in view of the urgency of the problems. An equal amount of effort must be spent on implementation and on studying the sociological factors involved in accelerating acceptance of IPM technology by growers.

Millet

This section relates primarily to the Sahel region of Africa where millet has traditionally been the staple food. While irrigated rice is beginning to make inroads, particularly among urban consumers, rainfed millet is still most important for meeting the food needs of the rural poor. The importance of millet will undoubtedly increase as populations grow, and the costs of new irrigation facilities, already among the highest in the world, become prohibitive.

The millet cropping system. Millet is grown in pure stands or mixed with other crops such as sorghum and cowpea. Farmers commonly adopt a three- to four-year fallow system. In West Africa, millet is grown as a rain-fed crop often in rotation with others such as groundnuts or maize.

Major pests. In the Sahel these include grasshoppers, millet earhead caterpillar *Rhaguva graminivora*, stemborers (*Sesamia* spp.), and meloid beetles. Other pests include downy mildew and smut of millet, and a variety of weeds, particularly *Striga*.

Present initiatives. Millet is the focus of considerable research in the Sahel region, most notably by the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) which operates regional centres in Niamey, Niger and a station in Kano, Nigeria. Some projects on crop improvement are country-specific and are supported by the United Nations Development Programme (UNDP), FAO, the United Kingdom Overseas Development Administration (ODA), Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), and other bilateral agencies. With support from the United States Agency for International Development (USAID), a local IPM project (CILSS - *see* Appendix 1) sought to introduce IPM measures from 1979-84. The project supported a range of activities including research, training and extension, and the establishment of the necessary local infrastructure. The project created awareness of the benefits of IPM in crop production, namely infrastructure, trained personnel and methodologies. The CILSS project facilitated the establishment of a Sahelian network on IPM research which has continued to function satisfactorily. Work in Mali, supported by the Natural Resources Institute (NRI), has evolved from a narrow insect-pest orientated approach to one in which non-insect pests and non-pest farming issues are being addressed in order to offer the rudiments of an IPM model.

Plant protection practices available to farmers. Farmers traditionally use smoke to repel blister beetles, and hand weeding and rogueing to control downy mildew. *Striga* is controlled through bush fallow rotations and organic manuring. Although farmers would generally be reluctant to purchase pesticides for what is largely a subsistence crop, pesticides are usually provided free to farmers by the national plant protection services to control grasshoppers and other major pests.

Current IPM technologies. Monitoring and surveillance for millet pests has so far been mostly confined to research, and has not been extended to farmers. Recent preoccupation with locust and grasshopper attacks has disrupted the development of routine monitoring and control systems. Decision thresholds have been formulated, but their use is mostly confined to research. Use of pesticides as part of an IPM strategy has been successful from a research perspective, but runs up against the farmers' economic constraints. Because of the heavy use of chemicals for locust/grasshopper control, however, free pesticides may be made available to farmers in the short term, which would temporarily skew the patterns of pesticide use as part of an IPM strategy.

Current impact of IPM. There has been no measurable effect of IPM on millet cropping systems. Although there are some reports of adoption by farmers, these are in the context of on-farm experiments. There is no evidence that sustained changes in farmers' pest management practices have occurred because of IPM project interventions.

New initiatives. Low-input approaches to IPM have potential, but require a greater appreciation of the constraints at both farm and institutional levels (*see Constraints on IPM Implementation*, p.45). National policies on pesticide prices, as well as donors' decisions to deliver emergency supplies for crisis management, also need to be reconsidered from a long-term perspective. Similarly, foreign-funded projects need to be sensitive to the dangers of short-term fixes which may disrupt the development of sustainable institutions and prove counter-productive to the objective of viable cropping systems. The situation in some Sahelian countries in terms of critical food needs; fragility of the system; opportunities for improved IPM through better appreciation of traditional cropping system approaches; and of knowledge of opportunities, constraints and defects of earlier IPM programmes, provides a strong case for examining how improvements can be implemented.

The CILSS IPM project, as well as other activities by bilateral and multilateral agencies operating in the Sahel, have already created awareness of IPM in the region and have laid the foundations for new initiatives that can consolidate existing activities. However, donor commitment and support over long periods of time are needed for these activities.

IPM of Striga

Striga spp. are parasitic weeds of cereals and cowpeas in many parts of the world, particularly Africa and India. They are associated with (but not exclusive to) low-input farming systems where they can, in severe infestations, cause total crop failure and make land unusable for growing susceptible crops. At present there is no single, reliable method of control which is appropriate to small-scale farmers, but there is a range of management strategies which, if integrated into crop production systems acceptable to farmers, reduce the damage caused.

Present initiatives. The *Striga* programme within the CILSS/FAO/USAID IPM project for the Sahel countries of West Africa has had mixed success. As a regional programme it has at least produced some surveys of *Striga*, several demonstration trials, and training of local scientists. In the Gambia, however, the programme has been moderately successful: comprehensive surveys and monitoring were carried out, and on-farm trials with good participation of the farmers were initiated, and continued after termination of the project. Partial control of *Striga* by integrated management techniques was shown to be possible. A follow-up FAO/UNDP project successfully tested and demonstrated integrated control packages for *Striga* on farmers' fields, as well as training Gambian field extension agents and farmers. A second phase of the same project introduced these IPM packages into the national extension service, but considerable improvements are needed.

An action programme for *Striga* control in Africa was adopted by the all-Africa government consultation on *Striga* in Marova, Cameroon in October 1986 (FAO, 1988). The consultation recommended that on-farm research in various African countries and cropping systems be initiated using available knowledge and practical integrated control packages for *Striga.* This should be supported and strengthened by new inputs arising from basic research and breeding programmes of the international agricultural research centres. Following the consultation, FAO and UNDP are supporting a number of national programmes in Nigeria, Burkina Faso, Zimbabwe, the Gambia and Cameroon to conduct on-farm research for the integrated control of *Striga.*

A network for *Striga* control was established at a regional workshop in 1988, bringing together experts from the various national programmes participating in the co-ordinated on-farm trials. The Institute for Agricultural Research at Ahmadu Bello University in Zaria, Nigeria was designated as the focal point for the network. This network meets once a year to assess results of on-farm trials, develop new strategies, and plan future activities; a newsletter to improve communication between countries is envisaged (FAO, 1991).

Plant protection practices available to farmers. Rotational cropping systems that appear to prevent *Striga* increase have been developed by some Gambian farmers. Late weeding and hand-pulling are also traditionally adopted. Other reported methods include fertilization; fallowing (including bush fallowing); rotation with non-susceptible crops; and intercropping. Despite these practices, losses still reach 10-35% of obtainable yield.

Current IPM technologies. Monitoring systems and decision thresholds (three *Striga* per m^2) have been used. Various improved agronomic practices, some based on traditional practices, but also including close crop spacing, clean seed and spraying with an appropriate herbicide, are recommended. An improved package is also recommended for general crop protection which includes methods against *Striga.*

There is some evidence of host-plant resistance to *Striga.* Some lines have been very successful and are being introduced to farmers in India. With institutional support, resistant varieties of sorghum and cowpea could help reduce losses due to this weed. Research is severely constrained by lack of institutional facilities, although IITA is attempting to rectify this and offers to play a co-ordinating role in the region. Long-term research on *Striga* is needed, based on increased and guaranteed support from development agencies.

Current impact of IPM. There are encouraging developments in some countries such as the Gambia, Cameroon, Burkina Faso, Zimbabwe, Nigeria, Ethiopia and Mali.

New initiatives. Although a great deal of information on *Striga* is available, much more relevant research is needed, as well as longer-term programmes for IPM implementation. Key requirements are better co-ordination and co-operation between plant protection services, research institutes and extension activities. Policy-makers must be convinced on how pest control should be organized. Project review missions tend to avoid mentioning such constraints. There is good potential for IPM of *Striga,* but any new initiatives must be conceived in relation to the solution of key constraints, rather than primarily in the context of scientific investigation.

Cocoa

Cocoa is an important small-scale cash crop in much of equatorial West Africa. It is being increasingly grown in South-East Asia by small farmers as well as in large commercial plantations. It is also grown in the Caribbean and parts of Central and South America.

The crop is often grown under shade with oil palm, coconuts, or planted shade or jungle trees. Small-scale farmers may interplant a variety of other food and cash crops, perennial and annual. Systems range from rainfed 'subsistence' through higher income farmers to major industrial plantations, the latter particularly in South-East Asia.

Cocoa pests. The major pests of cocoa vary from region to region; common problems include rodents, and also insects, notably Miridae in Africa and South-East Asia, and the pod borer *Conopomorpha cramerella* and stem borers *Xyloborus* spp. in South-East Asia. Diseases include *Phytophthora* in Africa, VSD, witch's broom in South America, and cocoa swollen shoot virus. Weeds are important during establishment of the crop, but not after good canopy formation. *Phytophthora* appears to be important everywhere. *C. cramerella* is serious in parts of South-East Asia, and cocoa swollen shoot virus is restricted to West Africa.

Present initiatives. There is no CGIAR institute responsible for cocoa. Government cocoa research institutes exist in Ghana and Nigeria, and major plantation organizations have research stations with pest management specialists.

In Trinidad, cocoa improvement programmes began over 40 years ago, and outreach programmes developed to include other Caribbean islands. The impetus came mainly from Trinidad, with support from the Cocoa, Chocolate and Confectionery Alliance (CCCA, now BCCCA) and the Caribbean governments, with later support from USAID, the American Cocoa Research Institute (ACRI) and consumer groups through co-operation with the Inter-American Institute for Co-operation on Agriculture (IICA) in Costa Rica. Help comes also from the Pan-American Development Foundation (PADF) and the London cocoa trade. In the Americas, there is a current USAID 'PROCACAO' project in Belize. In Ghana and Nigeria, a West African cocoa mirid and swollen shoot project was supported by the International Office of Cocoa and Chocolate. Other programmes have recently investigated *Phytophthora*. There has also been some emphasis on farmer training in correct pesticide application, as well as research on alternative pest control methods, which were intensified when subsidies on pesticides were removed in 1987. In the Caribbean, there has been some increased emphasis on improved planting material, with a recognized need for resistant cultivars; extension services have been strengthened in some islands. Recently, South-East Asian countries such as Malaysia have established their own Cocoa Board which supports research and provides marketing arrangements to improve quality.

Plant protection practices available to farmers. In South-East Asian plantations, a wide range of techniques are practised, including cultural and harvesting practices against *C. cramerella;* shade management against mirids; and pruning and uprooting for disease control. Host-plant resistance is not used in practice, although there is some evidence of varietal differences in susceptibility to most of the pests. Mechanical controls include early removal of *C. cramerella*-infested pods, as well as destruction of infested plantations and, in small-scale systems, the sleeving of pods to protect them.

The use of ants against mirids, pioneered in Indonesia before World War II, is now being recognized both in Indonesia and Malaysia. Other biological controls appear to be of little value against many of the pests. Quarantine regulations have been used in an attempt to isolate outbreaks of *C. cramerella,* and pheromones are used experimentally for mass trapping and monitoring. Chemicals predominate against major pests, with four to five sprays per season against *C. cramerella;* approximately monthly spray rounds against mirids in badly affected areas; and insecticides and fungicides to protect young plants, for example the injection of insecticides into xyloborid bore holes.

In West Africa chemicals also predominate, and there is much high-volume spraying against mirids, mealybug vectors of swollen shoot virus, and black pod disease. Mirids in this area have developed resistance to BHC and other chlorinated hydrocarbons. There have also been induced insect pest problems associated with pesticide use, notably increased numbers of *Characoma, Marmara, Tragocephala* and *Rathycoeila* species. There has been no significant evidence of pesticide-created problems in the Americas, probably due to lower pesticide use and elementary or non-existent controls. In South-East Asia in the 1960s, there was heavy defoliation of cocoa in Sabah by caterpillars, thought to be due to spraying with dieldrin. This situation subsided after dieldrin was replaced by different pesticides, applied less frequently. There is a serious potential danger of resurgence caused by the intensive spraying campaigns now being adopted for control of *C. cramerella,* with the widely used pyrethroid insecticides recognized as a frequent cause of resurgence.

Host-plant resistance is apparently of little significance for cocoa. Mechanical methods are used to remove black pods and swollen-shoot-affected trees, and there are recommendations for diversifying the system with interplanted non-host crops such as citrus and oil palm. Similar approaches to those in West Africa have been made in the Americas, but probably with less impact. Most small-scale farmers in Malaysia practise no controls, but a few use pesticides routinely.

Current IPM technologies. In some plantations in South-East Asia, simple action thresholds are adopted for pesticide application against mirids and *C. cramerella,* and a range of different control options against this pest are being studied. In Indonesia, some campaigns have been based on eliminating cocoa as soon as *C. cramerella* is detected in an area. However, no significant thresholds are in use for pesticide application decision-making in Nigeria, Ghana or in the Americas.

There is a sharp contrast in the use of IPM technology by major plantations and by most small-scale farmers, as seen in Malaysia. Major plantations each have a research and extension service, and Planters' Associations share experiences and employ scientists for work on critical problems such as *C. cramerella.* Some plantations have well defined pest control programmes, using herbicides for newly established plantations; insecticides and fungicides; sanitary procedures involving pruning of diseased stems and pods; as well as careful maintenance of shade and canopy to minimize certain pest problems. Ants provide important biological control of mirids in parts of South-East Asia and Cameroon, and more emphasis should be given to this. Overall there is little or no conscious integration, but the plantations have much to offer small-scale farmers in terms of a mix of controls that works.

New initiatives. There are notable opportunities for using existing knowledge to improve and introduce IPM based on hygiene, shade control, judicious use of insecticides and herbicides and biological controls by certain ant species. When control is vigorously pursued, there is over-dependence on insecticides. On current evidence, there are good opportunities for IPM adoption by small-scale farmers in particular, and also for plantation cropping. Cocoa should therefore be included among the priority crops for IPM implementation.

Cotton

Cotton is widely grown throughout the tropics, subtropics and warm temperate zones in small- to large-scale farms under rainfed and irrigated conditions. It is grown in mixed cropping systems, but usually as a monocrop in rotation with, for example, maize, groundnuts, tobacco, sorghum or wheat. In some countries, such as Pakistan and Sudan, there have been large increases in the area devoted to cotton. Production in most tropical countries is dominated by small-scale growers; in Zimbabwe, for example, they produce half of the total crop. Cotton is grown for cash, although crop residues may be important in some areas for animal feed and for fuel.

In many countries, cotton is heavily treated with insecticides - more are used than on any other crop. This has created pest resurgences and new pests, as well as resistance problems.

Cotton pests. Insects are the dominant problem, *Helicoverpa* and *Pectinophora* being the most widespread and often the most damaging pests. Species of *Spodoptera, Earias, Alabama, Dysdercus,* jassids, aphids and whitefly are of varying and more local importance. *Anthonomus* is the most serious pest in parts of South America, where it is spreading. Some diseases, e.g. blackarm, are controlled by host-plant resistance. Weeds are controlled by hand or by tractor-driven cultivators.

Present initiatives. FAO/UNEP (UN Environmental Programme) have had a long-standing commitment to cotton IPM because of excessive pesticide use and the associated problems. They have supported programmes in Nicaragua, Syria, Sudan and elsewhere. There is also long-standing ODA support to Malawi, Zimbabwe, Pakistan and Egypt. Projects are currently operating in all these countries (except Malawi) and in Peru, and there are modest inputs in Paraguay, the Caribbean and elsewhere. An international agency is now being built up under French aid.

Plant protection practices available to farmers. A good example is that of Zimbabwe, where *Helicoverpa* is the key pest which, before insecticides, drastically decreased yields. The pest management strategy depends on a combination of jassid resistance; a legally enforced closed season to stop pest carry-over, especially of *Pectinophora;* and chemical controls based on 'scouting' to determine the need to spray and the insecticide used. Certain chemicals such as pyrethroids and acaricides, which tend to cause resurgences, are strictly controlled. All Zimbabwean farmers follow this programme to varying extents, and this has stabilized cotton as an economically valuable crop in Zimbabwe. In Malawi, however, there is a lack of extension and training, along with other constraints.

Current IPM technologies. The technologies used in Zimbabwe are described above, and there appear to be no notable harmful side effects from IPM-based insecticide use in that country. Elsewhere, some decision thresholds have been established. In Egypt, Pakistan and Peru, for example, farmers are advised to base chemical applications on such thresholds. Work on host-plant resistance is being carried out in Pakistan and Zimbabwe, and pheromones are used in several countries for monitoring *Pectinophora.* Pheromones are also used for direct control of *Pectinophora* in a part of Egypt.

Most countries have controls on certain environmentally hazardous chemicals, including those which upset natural biological controls. No special work is being done on biological control, except in terms of using relatively selective insecticides, and avoiding their use when it is evident that natural biological controls are being affected - notably early in the season. In Egypt, emphasis is placed on delaying insecticide applications until as late as possible, for example by the early-season collection of *Spodoptera* egg masses by hand. Experiments have been carried out with selective viral insecticides.

New initiatives. In countries where cotton production has increased, there has been too much reliance on insecticides. In general, more sustained programmes are needed for the implementation of IPM, with associated research including support from the agrochemical industry. In particular, more selective control agents are needed, along with improved scouting techniques which are acceptable to farmers, leading to better timing and application of suitable insecticides. Much depends upon improving the skills and status of extension workers. Zimbabwe, which still lacks sufficient extension facilities, nevertheless has a good IPM programme which could be applicable to rainfed cotton production elsewhere. Thus large cotton growing areas of Tanzania, for example, could benefit from programmes that aim to apply existing knowledge as well as to develop new technology. Cotton is undoubtedly a priority crop in view of the intensive use of chemicals and the near-crisis or crisis situations which exist in some countries.(N.B. *The World Bank has forecasted a decline in real cotton prices over the next decade. If this turns out to be the case then the extent to which IPM efforts will be supported might be qualified.*)

Soybean

Soybean is becoming an increasingly important protein cash crop in the Americas and in Asia. It is grown by small- and large-scale farmers, as well as industrially in some countries, but the following information relates solely to parts of Brazil where it is grown mostly by higher-income farmers in an area of about 11 million ha. In Brazil there is a simple rotation, usually based on soybeans in summer and wheat in winter.

Soybean pests. The major insect pests are defoliators - notably the velvetbean or soybean caterpillar *Anticarsia gemmatalis,* and a complex of pentatomids which are key pests feeding on pods and seeds - both of which are widely distributed. Foliar diseases include *Cercospora* and some soil-borne fungi. There is a complex of weed species.

Present initiatives. An IPM programme in Brazil has been co-ordinated by EMBRAPA (*see* Appendix 1). A range of organizations has helped develop the programme, notably the National Soyabean Research Centre, Instituto Agronomico do Parana, and ENATER (extension services), with funding largely through the Government Ministry of Agriculture. The programme developed in response to damaging over-use of insecticides, particularly organochlorines. Pest resurgences were common, but after initiation of the IPM programme the number of applications fell from nearly six per season to fewer than two within three years. So far there has been no evidence of resistance to pesticides.

Plant protection practices available to farmers. A weekly TV programme in Brazil informs farmers of pest occurrences based on extension monitoring, and includes information on natural enemies. Decision thresholds are available for key insect pests. Cultural controls include use of early-maturing varieties to avoid damage by pentatomids, early planting to avoid thrips vectors of virus diseases, trap crops for pentatomids, and proper soil management to avoid soil-borne diseases. All the distributed varieties are resistant to foliar diseases, and the variety IAC-100 to pentatomids. Some recent varieties are resistant to nematodes. The use of dangerous and non-selective chemicals has been abolished, and products are recommended on the basis of their selectivity and minimum effective rates. Only eight products are recommended at present for velvetbean caterpillar, compared with about 20 previously. Two biological pesticides, including a nuclear polyhedrosis virus (NPV), are used against velvetbean caterpillar. This has also greatly reduced hazards to the human population. Appropriate information is available to farmers and has strong local political support, because IPM has been shown to increase profitability.

Current IPM technologies. These are outlined in the paragraphs above.

New initiatives. The above methodologies indicate the research and development initiatives which are needed. The successful implementation of IPM in southern Brazil is an object lesson for elsewhere, but clearly needs adaptation for other regions. There is great potential for the techniques being developed in Brazil to be adapted for use in other South American countries, and they are likely to be relevant elsewhere, for example in Asia.

Maize

Maize, with wheat and rice, is one of the three basic food crops and is widely grown in the tropics, subtropics and warm temperate zones in farms ranging from subsistence to large-scale, rainfed and irrigated. In Central and South America maize is the most important food crop and is grown on a rotation system - small farmers usually intercrop maize with other food crops, notably beans, and also cassava. Maize is mainly grown in the first growing season, with more beans and less maize in the second.

Maize pests. The most widespread insect pest is *Spodoptera frugiperda.* In Central America it can cause yield losses of 30-60% unless controlled. Other Lepidoptera that either defoliate the plant, feed on cobs or are stemborers include *Mocis latipes, Helicoverpa zea,* and *Diatraea* spp. *Dalbulus maidis* (Hemiptera) is a vector of stunt disease. Other diseases include downy mildew, and there is a complex of weeds.

Present initiatives. FAO supported a programme for IPM on cotton and basic grains, including maize, from 1974-79. This project received high priority from the Nicaraguan Ministry of Agriculture. What is being done now is not evident from the questionnaire. In Latin America, subregional programmes such as the PCCMCA/CIMMYT and the AID/CATIE/IPM projects and IICA (*see* Appendix 1), have included maize in their working plans. Several countries have national programmes covering maize, with assistance from USAID, GTZ and the Netherlands.

Plant protection practices available to farmers. In the Pacific region of Central America, 90% of farmers make about four applications of insecticide anually to control *S. frugiperda* in maize. In the interior there is more traditional agriculture and fewer applications are made. Traditional treatments against *S. frugiperda* include putting soil into the whorl of plants to destroy larvae. There is also a danger of carry-over from other crops - it is thought that about 80% of farmers use unnecessary or doubtful pesticide applications, and that the typical 20 applications per season to cotton have caused outbreaks of *S. frugiperda* and other pests on maize and beans.

In South and Central America, early planting and tolerant varieties are used against maize stunt, seed sanitation and seed treatment against downy mildew, and insecticides against *S. frugiperda.* It is thought that the maize crop represented a balanced agro-ecosystem before the introduction of modern pesticides, but their excessive application has created resurgences and secondary pest outbreaks, e.g. of *Helicoverpa,* as well as failures in control due to suspected insecticide resistance, and the loss of disease tolerance in the crop.

A range of methods other than conventional insecticides are available or being developed against *S. frugiperda* and stemborers. These include cultural practices, use of natural predators and parasites, and release of some biological control agents including pathogens.

Current IPM technologies. In Central America these include decision thresholds for *S. frugiperda,* and a range of cultural practices (including intercropping, ploughing, weeding and planting date) which decrease insect pest attacks. Parasitoids of *S. frugiperda* have been identified, but no work has yet been done to improve their efficacy. Similar thresholds and more cultural practices are available in parts of Latin America where farmers also recognize the benefits of an IPM approach. Imported pesticides would require foreign exchange; thus the emphasis is now on locally available controls.

New initiatives. There seem to be no major initiatives which would currently fulfil requirements for a major improvement in IPM implementation. Maize and associated crops in the Americas would be very strong candidates for improved IPM.

Potato

Potato is an important commodity and is produced on small farms in highland, rainfed, sloping areas of Central America in combination with other vegetables, maize, and grassland for dairy cattle.

Potato pests. Key pests are two species of tuberworm, *Scrobipalpopsis solanivora* and *Phthorimaea operculella.* Other important pest problems include early and late potato blights, nematodes, white grubs, leaf hoppers, agromyzid leaf miners, potato aphids and whitefly (*Bemisia* spp.).

Present initiatives. Following on from the basic research progress made by Centro Internacional de la Papa (CIP) on alternative methods for tuberworm assessment and control, and under the influence of the strong environmental movement currently existing in Costa Rica, the Ministry of Agriculture's Department of Entomology has started studies in farmers' fields to evaluate IPM techniques.

Plant protection practices available to farmers. As with most farming agro-ecosystems, potato pests in Central America have been controlled solely with pesticides. Chemical control is based on the intensive use of a large number of different types of insecticides, fungicides, nematicides and herbicides, with the pyrethroid insecticides being preferred. Rotation with other vegetable crops is a common practice. Dairy cattle are also allowed to enter fields after harvesting to graze on crop residues and weeds.

Current IPM technology. Potato tuberworm monitoring, and the establishment of action thresholds using pheromone traps, are being implemented in a small potato-growing area of nearly 300 hectares involving about 70 farmers. The technique has permitted a substantial reduction of pesticide treatments as action thresholds are rarely reached. As the adult tuber moth population is scarce, the pheromone traps also act as an effective control method. An additional crucial benefit is the increased activity of the natural enemies which keep other potato pests in check. The programme is accepted by more farmers because of the lower production costs and the improved yield and quality of potatoes.

Pasture lands

Grass for cattle forage is grown in the highlands of the Central Cordillera of Costa Rica and other countries of Central America, mostly for milk production. In these areas, cattle breeds are of European origin; in the more extensive tropical savannahs the dominant races are the Hindo-Brahmanic.

Pasture cropping system. Although most pasture lands are basically monoculture, long-period rotations with horticultural and basic food grains are not infrequent. Improved, often exotic grass species and varieties have been introduced, as well as new technologies on range management. Fast-growing grasses, grazing rotation and fertilization have produced important changes in the grassland ecosystem, creating conditions for the development of new pest and weed problems.

Grassland pests. Under the above conditions, spittle bugs (*Prosapia* and *Aeneolamia* spp.) have become major problems, making the forage unpalatable and poisonous to cattle. Infested plants are weakened or killed, leaving space free for invasion by weeds.

Plant protection practices available to farmers. Damage caused by spittle bugs is controlled by farmers using chemical pesticides. Destruction of the most important natural enemies has induced pest resurgence and secondary outbreaks of the grass loopers (*Mocis latipes*) and white grubs (*Phyllophaga* spp.). Weeds, mainly *Sida, Bidens, Lantana,* and *Rottboellia* have become serious in heavily infested farms.

Current IPM technology. Biological control has become a major strategy of pest control, with the discovery of effective action by the fungus *Mucor* sp. on the control of the spittle bugs. This entomopathogen is isolated and reproduced in the laboratory and its spores are harvested and spread in the infested fields - this practical technology can compete with chemical pesticides which are costly in both financial and ecological terms. In addition, action thresholds for spittle bug control have been established, as well as cultural control practices.

Current impact. At present, more than 200 farmers owning 15 000 hectares of pasture land have adopted the use of *Mucor* with excellent results. Milk produced by cattle in the treated areas does not contain pesticide residues and it is accepted that the practice has had a favourable effect on the environment and on the quality of life. Economically it is of undoubted benefit.

New initiatives. Although the progress achieved has been obvious, IPM must be expanded through intensive training of technical and extension staff as well as farmers. Improvement of laboratory production techniques, the establishment of more spore production units and the implementation of proper marketing techniques will permit a generalized adoption of IPM. This could extend to the rest of the Costa Rican cattle areas, as well as possibly to the other countries of Central America and the Caribbean. Small investment is required from external donors to support with 'seed money' the expansion of this effective IPM programme.

Wheat

This section is confined to wheat in parts of Latin America. Wheat is an important crop in temperate and highland areas of Latin America and is produced both in rainfed (tropical highlands) and irrigated (temperate lowlands) small and large holding units.

In temperate climates, wheat is a winter-spring crop in rotation with fodder legumes and industrial crops like sugar beet, rapeseed and sunflower.

Wheat pests. In South America, major wheat insect pests are cereal aphids, especially *Sitobium avenae* and *Metapolophium dirhodum* which are both vectors of the cereal barley yellow dwarf virus disease. Stem borer, *Hyperodes bonaeriensis,* is a secondary pest.

Present initiatives. Most species of wheat aphids have now been successfully controlled with classical biological control programmes based on the parasitoids *Aphidius ervi, A. rhopalosiphi, Praon volucre* and *P. gallicum.* They give complete control of the aphids in Chile, and are also used in Brazil, Argentina and some wheat-growing areas of Peru and Bolivia.

New initiatives. The recent introduction of the Russian cereal aphid *Diuraphis noxia* in the area is a serious threat to the stable wheat ecosystems of the South American zone countries. International support is urgently required for the search for and introduction and colonization of its natural enemies.

INSTITUTIONS SUPPORTING IPM

Current institutional structures

The following description of current institutional structures supporting IPM is based largely on a review by James (1990), prepared for this study. Copies of this review are available on request to M. Iles (address in Appendix 2).

Developing countries

Farmers and farmer groups. In the context of development work, 'farmers' are small-scale, low-income and resource-poor. They are the intended beneficiaries and ultimate users of all IPM research output. Recurring features in successful agricultural research outputs adopted by farmers are linked to genuine consultation with the farmers at all stages of the research process. This begins with the identification of the problem, through research design, to the development, testing and evaluation of recommendations.

Because of the enormous variation in circumstances of the target beneficiaries of research, flexibility is needed in the research system. Farmers cannot be provided with a particular 'package of recommendations', because these are unlikely to match their individual circumstances. External solutions have a low probability of working in the long term; 'packages' of external solutions are almost certain to fail. The active involvement of farmers in designing IPM solutions to fit their specific circumstances is of vital importance, but is rarely achieved. However, limits to the contribution that farmers are able to make to the research process need to be recognized, and account must be taken of their lack of technical knowledge.

Informal groups of farmers or neighbours (who may include some non-farmers) often make joint decisions about agricultural practices, including IPM. Farming groups that have formed for various reasons (e.g. village administration, irrigation management, or religious purposes) can serve as an important institutional basis for group decision-making about cultivation practices, purchasing chemicals, and co-ordinating the use of IPM methods.

National extension services. These are primary institutions, having responsibilities within the national programme to serve the IPM needs of their client farmers. Training and assisting farmers or farmer groups in implementing IPM is their principal role. Limitations in transportation, human resources and lack of incentives and motivation often preclude many extension services from providing an effective service. Extension services are often found to be inadequate, with limited abilities for transferring technology and training, and a poor understanding of the socio-economic aspects of IPM and the requirements for implementation at farmer and community levels.

Crop protection technical services. This is a group that acts as the interface between research and development institutions and extension, and in many countries is responsible for the adaptive research necessary to generate information for IPM implementation. Many of these services also fulfil the regulatory functions for pesticides and plant quarantine, and operate pest diagnosis laboratories; they are therefore the 'synthesizers' of information for extension. The vitality and role of this group deserves recognition and strengthening in terms of both training in contemporary IPM technology, and support for implementation activities.

The research and development institutes of the developing countries have a mandate to work with both farmer and extension service. Identification of a farmer's perceived and assessed needs, followed by the development of appropriate research aids and products for IPM, is their principal role. However, constraints related to equipment, facilities and lack of motivation are significant, and morale is low. Unfortunately even when research is conducted by national research and development institutes, it is often inappropriate, being designed to respond more to research requirements than to farmers' needs.

A major institutional constraint in most developing countries is that work on resistance breeding and cultural practices is part of the research programme; research on pesticides, survey monitoring and other aspects of control, along with operations on pest outbreaks, fall within the plant protection service; and extension is often the responsibility of yet another body. This organizational fragmentation precludes the effective implementation of an IPM programme; integration of these activities is essential.

Educational institutions. Education is the key to a long-term change in plant protection philosophy in developing countries. With IPM, a concept which is based strongly in ecology and systems science, few universities in developing countries can take advantage of contemporary ideas and technology in their curricula. Any new initiatives on IPM need to recognize the role of educational institutions as trainers of future generations of plant protection scientists. In view of its crucial importance, education is discussed further below.

National governments. It is not sufficient for governments merely to define policies. Policy implementation through action by appropriate pricing systems, support for credits and inputs (without abusing pesticide subsidies), and sometimes the regulation of cropping practices are prerequisites for implementation of effective IPM programmes.

Although many governments in developing countries have declared policies for increasing food production (often including the implementation of IPM within the context of sustainable agriculture), in some countries these policies are often not enacted and there is no real commitment to the stated goals and objectives.

Non-government organizations (NGOs). There are many local and expatriate NGOs in developing countries; they have been active in the promotion and implementation of IPM programmes at the grass-root level, particularly in poor communities, and have a comparative advantage in the 'bottom-up' as opposed to the 'top-down' approach. By many standards, their contribution to IPM may be judged successful.

The comparative advantages of the NGOs are: a better understanding of the needs of poor farmers; realistic judgement of limitations to the adoption of sophisticated technology; and the need for simple technology if the aim is adoption at the farmer level. NGOs have a comparative advantage in crucial areas where many development agencies are deficient, and this applies to IPM.

International Agricultural Research Centres (IARCs). The major contribution to crop protection, as opposed to IPM, made by the IARCs is through research (mainly germplasm development), and more specifically through the development of disease and insect resistance. Whereas their input in terms of resistance breeding has been outstanding, it is also true that this is a very narrowly based contribution to IPM. Some centres have also done limited work with pesticides and cultural practices in conjunction with resistant varieties, but incorporation of host-plant resistance is by far their major contribution. The Africa-Wide Biological Control Program (ABCP) at IITA is an exception in that it concentrates on classical biological control of cassava in Africa.

IRRI and FAO/UNEP have also collaborated in developing methods for preserving biological control of rice insect pests, and have successfully extended these techniques for use by rice farmers in Asia. CIP also has research under way on the use of pheromones, control of virus diseases, and biological control for reducing losses from potato pests.

The principal mandate and comparative advantage of the IARCs are in the development of research tools or products, rather than in assisting national programmes or regional institutes in implementing IPM programmes. It is significant that, although the mandate of the IARCs includes most of the important food and feed crops, it excludes many of the important cash and all the industrial crops. Many of these (e.g. vegetables and cotton) are important targets for IPM because of heavy pesticide usage, and also because many farmers in developing countries depend on them for essential income. There are also a number of international agricultural research centres which are not formally members of the CGIAR, but which are supported by several bilateral and multilateral agencies and have interests in pest management: ICIPE and AVRDC.

The International Centre of Insect Physiology and Ecology (ICIPE) is based in Kenya and conducts research in entomology. Its initial work programme concentrated on basic research, but is now more closely orientated to insect pest control, for example in co-ordinating PESTNET, a network of pest control programmes in Africa. The fact that ICIPE works only on insect pests limits its contribution to IPM; nevertheless it has important attributes for both research and training, particularly important in Africa, where the shortage of trained human resources is a major constraint.

The Asian Vegetable Research and Development Centre (AVRDC) is based in Taiwan and, although located in Asia where almost all its current efforts are concentrated, it has a global mandate to improve vegetable production for the developing countries of the tropics. AVRDC is already involved in the development of IPM research tools and products for vegetables in Asia, and is co-operating with many national institutions, some of which have already initiated programmes, for example in the control of diamondback moth on crucifers. Vegetables are a top priority for IPM (*see Vegetables,* p.19).

Commodity Research Organizations. Many of the international research centres noted above are focused on particular crops, but do not cover important commodities which are targets for IPM such as cotton, cocoa, coffee, oil palm, rubber, coconut and date palm. There is no institutional mechanism at the international level to establish a research effort and to provide the focal point for information exchange. There are, however, several strong national research institutes in the developing countries which perform a similar function to the international research institutes through informal collaboration. Examples include the Rubber Research Institute in Malaysia; coffee research institutes in Kenya and Brazil; date palm centres in Iraq and Morocco; and coconut research institutes in several countries. It would be feasible to link the principal national research centres for any crop not currently represented by an international centre into a network for co-ordinating IPM research and technology transfer to interested national programmes. Some major industrial plantation organizations also have research stations which can make an important contribution to IPM, for example, for cocoa and oil palms.

Regional institutes and organizations. There is another group of regional organizations that assist or could assist in the implementation of IPM programmes within their region, e.g. CILSS or SADCC in Africa. Although regional organizations have implemented successful regional programmes, experience has generally indicated that project implementation via these organizations has been difficult.

Multilateral organizations

The Food and Agriculture Organization (FAO) of the United Nations and the Commonwealth Agricultural Bureaux (now CAB International, CABI) are the two most important multilateral organizations, making a significant contribution to IPM.

The Food and Agriculture Organization of the UN (FAO). FAO has initiated action to promote IPM in the 1960s and has held several important symposia and workshops. It has organized regional IPM implementation programmes (often with special project support from its member countries), and supported national programmes such as those on strengthening the plant protection services. A panel of experts was formed in 1967 to advise FAO/UNEP in promoting and implementing IPM projects.

The most successful project currently operated by FAO is the Development and Application of Integrated Pest Control in Rice Growing in southern and South-East Asia (*see Rice,* p.16). FAO associates with IRRI to develop research inputs, but the outstanding emphasis is on training farmers in distinguishing pests from beneficial species; monitoring; and more effective decision-making to ensure that minimal pesticides are applied correctly and safely. A major achievement has been the training of approximately 365 000 farmers; savings due to decreased use of pesticides are estimated at US$ 150 million per annum.

An example of a less successful project is that on Research and Development of Integrated Pest Management for Basic Food Crops in the Sahel. The constraints included lack of government commitment; insufficient trained personnel; weak or non-existent plant protection services; heavy reliance on subsidized or donated pesticides; and lack of co-ordination amongst bilateral and multilateral development agencies in relation to pest control in the region.

The IPM programmes executed by FAO have mainly concentrated on insect pests, with much less attention being given to diseases and weeds. FAO must continue to play an important role in the implementation of IPM programmes. It needs to be assisted in this task by the mobilization of broader support, co-operation and co-ordination within the development, scientific and client communities.

Commonwealth Agricultural Bureau International (CABI). Under its new consolidated management structure, CABI provides a range of services to national programmes that represent critical inputs for the effective planning and implementation of IPM programmes. The diagnostic services which it provides to developing countries in the identification of plant pathogens and insect pest problems are invaluable, as are as its new programmes to strengthen national and regional pest diagnostic capacity. Its comprehensive information services in agriculture will become increasingly important in a world where access to state-of-the-art information is essential if duplication is to be avoided, and progress accelerated in the development and implementation of IPM.

Of particular relevance to IPM is CABI's International Institute of Biological Control (IIBC). For over 60 years, IIBC has been providing an international service in biological methods of insect pest and weed control, and presently operates over 25 programmes from seven stations around the world. These include strategic regional bases linked to national programmes in Trinidad and Tobago, Kenya, Pakistan, India and Malaysia. IIBC assists national programmes in all aspects of biological control; it also provides information, advice and regular regional training programmes in biological control.

While CABI's activities in pest management are largely linked to national programmes, it also maintains close research and information links with the IARCs. CABI's comparative advantage is that it can offer an array of services that constitute some of the essential inputs required for the development and implementation of IPM programmes.

International Organization of Biological Control (IOBC). Set up in association with the International Union of Biological Sciences (IUBS), the IOBC provides information through its newsletters and scientific journal, *Entomophaga.* It has limited funds which it utilizes to support working groups by co-ordinating research, mostly in its West Palearctic Regional Section.

International development agencies. Several multilateral and bilateral development agencies have substantial investments in pest management projects. The range of activities and *modus operandi* of some of these agencies is discussed by James (1990). A conservative estimate of annual expenditure on IPM-related activities by bilateral agencies is US$ 100 million (*See* Annex II of James, 1990 for further details of projects and expenditure by selected agencies). The multilateral agencies are providing at least a similar amount annually in loans and grants.

Many bilateral agencies are supporting research and development work on IPM in both industrialized and developing countries. Bilateral agencies also procure and donate significant quantities of pesticides to developing countries. Most of the effort in bilateral programmes is in the implementation of IPM projects, which generally has not achieved the desired level of success.

The adoption of pesticide procurement guidelines by agencies must incorporate principles that help prevent the environmental and health problems caused by the excessive use of pesticides. Direct efforts by international development agencies to promote the wider implementation of IPM in developing countries can be greatly strengthened by ensuring that their internal IPM criteria are consistently applied to all their agricultural development efforts involving pesticides.

There has been only limited co-operation amongst the international development agencies in the conduct of IPM projects. There is increasing interest in establishing collaborative activities supported by several agencies when a 'critical mass' of expertise and resources is required to solve a particular problem. A recently established programme for the biological control of locusts and grasshoppers, jointly funded by IIBC, the Department de Formation en Protection de Vegetaux, Niger (DFPV), and IITA, is evidence of this emerging approach.

World Bank. The World Bank has recently prepared its *Guidelines for project design, appraisal, and supervision in relation to agricultural pest management* (World Bank, 1985): these propose IPM as the central strategy for all the World Bank's agricultural development lending, which includes pest control components. The guidelines elaborate recommended project components for IPM research, including studies on the agro-ecosystem and on genetic, cultural and biological control methods. The integration of farmers into all stages of Bank-supported pest management research is considered necessary, as well as investigations and critical evaluation of traditional pest management practices to determine their potential for IPM. The guidelines also cover training and extension, and policy issues affecting recipient countries.

Full implementation of these IPM guidelines should result in an increase in World Bank support for IPM; this is largely due to a careful review of all agricultural lending projects at the early stages to ensure their consistency with an IPM strategy, and to ensure that the local conditions are suitable for effective implementation of the strategy.

Research and development organizations in industrialized countries

The comparative advantage of research and development organizations in industrialized countries is in developing research tools, products or protocols, and in providing technical expertise to the executing agencies who are implementing IPM programmes in the developing countries. Experience has shown that extrapolating results from industrialized countries to meet the different needs of the developing countries can result in the transfer of inappropriate technology. This is probably the key hazard in attempting to utilize the considerable resources of this group.

Private sector

The current major input to IPM from the private sector is the research, development and distribution of pesticides, estimated at an annual market value of US$ 20.5 billion. Whereas the private sector is often seen by its critics to be interested primarily in exploiting sales of pesticides, it possesses skills and experience, some of which are unique, which could be utilized more effectively by the public sector.

Approximately one-quarter of the total pesticides used are applied to fruits and vegetables. Five crops: rice, cotton, maize, wheat and soybean, receive approximately the same volume of pesticides, each equivalent to about 10% of the global market. It is probable that the mix of products contributed to IPM by industry will change in the future because of the rapid development of biotechnology. At present, biotechnology has yet to prove itself in relation to IPM. As a result of the development of gene products conferring resistance to insects and pathogens, it is forecast that relative usage of conventional insecticides and fungicides will stabilize or decrease, whereas herbicide use will increase as herbicide resistance genes are incorporated in crop plants.

Thus future developments may allow industry to participate more fully in IPM, as the private sector will be engaged in the development of superior research tools, and of products other than pesticides which could make an important contribution to IPM.

Training

Training in crop protection with special reference to IPM has frequently been highlighted in the past by FAO, the World Bank, UNDP and bilateral programmes. Funds are available from many different sources for overseas training for personnel from developing countries. Some forms of training, such as those involving a split between the home and host countries, have particular merit. Most training activities need better co-ordination and focus. A recent feasibility study by the Agricultural University in Wageningen, the Netherlands, on needs and constraints of information and documentation for IPM in the tropics, is relevant to such problems (Van der Weel and Van Huis, 1989).

Training of the different groups involved in crop protection is vital to technology transfer and IPM implementation. This has not been sufficiently emphasized in most national IPM programmes. Training must target the following groups: farmers (as the final client group); extension workers; crop protection technical services personnel; researchers; trainers (tertiary and secondary); and policy makers. Currently, training materials, curricula, trainers and evaluation materials are lacking for many crops. Because the majority of farmers in developing countries are illiterate and often poor, the extension of IPM as new technology is a matter of human resource development. This suggests that the type, method and content of training should relate to local conditions in addition to just presenting the technical aspects of IPM.

Training deserves high priority and unless given due attention will remain a serious bottleneck to the implementation of IPM.

Farmers

The lack of IPM information for farmers and extension workers is still a major constraint in many countries. More important is the nature of the material available - it has been shown (Escalada and Kenmore, 1988) that many messages carried in posters, for example, are not understood by farmers. With the exception of data collected by the FAO Regional Rice Integrated Pest Control Project, few data seem to be available on how many farmers have been exposed to the IPM concept. As noted earlier, approximately 365 000 rice farmers, 36 000 village extension workers and 1700 trainers have heard about IPM through programmes sponsored by the FAO regional IPC project and associated national agricultural systems.

Perhaps more critical than the number of farmers trained is their ability to retain IPM skills, such as monitoring for pests, identification of beneficial organisms, and correct diagnosis of problems. Data from the Philippines show that even three to four years after a session, trained farmers showed more understanding than untrained farmers in their ability to diagnose pest problems, to recognize natural enemies, and to apply thresholds. Trained farmers tend to make fewer insecticide applications.

Apart from skills development, farmers exposed to IPM training appear to have increased self-esteem and perceived control over their environment. These parameters are difficult to quantify, but the experience from other countries seems to confirm the Philippine example.

The limited educational background of farmers impedes IPM implementation in some countries, although workers feel that, with the appropriate involvement of farmers in technology testing, receptivity of IPM could be higher. There is evidence that even farmers with little education are able to understand and apply thresholds for insects. There is therefore a need to involve farmers in the development of IPM training material, much more than with other aspects of new technology, because of the knowledge nature of IPM technology. Furthermore, the role of NGOs and of farmers themselves in providing training should be encouraged.

FAO estimates the number of rice farmers in Asia to be 10 million. Therefore, if only 365 000 farmers have so far been trained directly in IPM, then in terms of social impact this technology has reached only 3.65% of rice farmers. The proportion becomes even smaller in terms of the general farming population in Asia and throughout the world. If IPM is to work, then farmers' information needs will have to be satisfied more quickly. The training and visit system, even if actively implemented, only reaches a small proportion of farmers. This is also the case with the demonstration plot and group meetings used by the FAO programme. The constraint therefore appears to be generating the right message about IPM for a particular farmer group, and finding a way to get it across in the most relevant manner. It will therefore be necessary to explore alternative, perhaps novel and unconventional methods of training that can increase the exposure rate of IPM.

Village-level extension workers

Together with NGO personnel, extension workers are the frontline workers on IPM. Many do not have specialized training in plant protection, let alone IPM, and they have other duties. The evidence from Asia shows that this group requires training, using knowledge in a synthesized form, including generalized principles.

The influence of the agrochemical industry is also a major factor to contend with in government efforts to implement IPM. Farmers are not helped by what appears to be a direct conflict between industry's objective of more sales, and the IPM message of rational pesticide use. This points not only to the need for private industry and public sector extension to work in a more complementary manner, but also for training programmes that would reconcile the perceived conflicts between the aims of the two groups.

Crop protection technical services personnel

Crop protection technical services personnel group act as the interface between village-level extension workers and researchers in many countries. Often they are people with science degrees or diplomas in plant protection disciplines, and they play an important role in adaptive research and training of extension workers. The relatively low status of plant protection workers in the administrative hierarchy is a major constraint in efforts to improve plant protection generally. Associated with the above is the morale and financial standing of these workers. There are many examples of workers who have impressive programmes on paper, but in practice do not have the funds to travel and execute them. However, it is possible have some impact on the quality of this group's IPM knowledge by holding targeted training sessions which emphasize field work. National programmes that work with the FAO rice programme have so far trained about 1700 technical service personnel.

Research workers

Field research on IPM presents many difficulties, and all too often research workers, through inexperience or ill-conceived ideas on how to answer a question based on a particular need, fail to design the relevant experiments, including failure to appreciate quite simple distinctions such as whether particular statistical methods are or are not needed. Whilst profound new technology skills are needed for certain kinds of research, much important developmental research is empirical and requires understanding of traditional research methods best learnt from workers with appropriate research experience. This also underlines the need for a research methodology manual specific to IPM: no such manual has yet been written.

One impact of the rice IPM programme is a greater awareness of the need for rational deployment of new technologies by plant protection scientists, especially with regard to the impact of this technology on the social, political and biological environment. Research institutes such as IRRI have recently changed their focus from host-plant resistance to recognize that it is only one component of a total basket of tools. Talking about integration, however, is easier than carrying it out. IPM research is interdisciplinary and requires knowledge that is not included in more conventional, disciplinary plant protection courses. Because many researchers in developing countries have not been trained to do 'integrative', holistic or ecological research, this is presently a bottleneck in the information generation process. The initiative taken by the Netherlands (de Vries Penning *et al.* 1988) to impart skills in systems analysis to Asian researchers is an exemplary one that could be used as a training model for researchers on this new approach.

Many training meetings with an IPM theme have been held world-wide by bilateral and multilateral development agencies for researchers. The impact of these on research output is difficult to determine, although it is known that such meetings have catalysed further work. The critical issue is how appropriate the training has been in terms of imparting knowledge on techniques to conduct IPM research. In addition, new knowledge on aspects such as environmental assessment need to be incorporated.

Universities

Universities in many developing countries are now teaching the IPM concept, and it is hoped this will significantly affect the direction of plant protection in many countries in the next decade. However, because many of the developing countries have separate institutions for research and for tertiary training, it is important that opportunities be found for the latter group to be periodically updated, or to participate in IPM research and implementation. This is vital because no amount of training in IPM concepts will equip people for working on its implementation, and there is a danger that IPM may be idealized until it becomes impractical. It is also important that links be strengthened between academic institutions in the industrialized countries with strong expertise in IPM, and those in the developing world interested in upgrading their expertise.

Relatively few institutions in the developing countries of the tropics offer tertiary education in IPM. The situation in the industrialized world is better, and there is at least the opportunity for integrative courses. Many of the present and future educators of the developing world have been and will be trained in the industrialized countries, and will acquire IPM skills. Unfortunately, they may also reflect the disciplinary departments in which they have done their advanced training. Agricultural universities in both developing and industrialized countries should be encouraged to develop interdisciplinary plant protection programmes which will expose students to all aspects of IPM.

Production credit institutions

Credit institutions represent an important opportunity for promoting the wider implementation of IPM, particularly for input-intensive cropping systems. Beyond the direct contact between loan officers and individual growers, in which production plans for the coming season are negotiated, banks can play a broader role in promoting IPM. Activities might include the production and distribution of relevant IPM manuals to growers, the sponsorship of meetings, workshops and symposia, and the dissemination of information. Examples include the role played by the National Bank of Nicaragua in promoting cotton IPM among growers, in collaboration with the FAO's efforts on cotton IPM.

Agricultural banks should play a greater role in promoting wider implementation of IPM in order to reduce the multi-year risk to loan portfolios in input-intensive commodities, in which they have substantial exposure. Bank lending practices can contribute significantly to promoting IPM: the consequences of pesticide overuse are a threat to sustainable production. In many cases, loan officers will insist on the purchase and use of pesticides by the grower as part of the overall input-credit package, rationalized as a necessary term-of-loan condition to provide 'insurance' against serious crop losses due to pest damage, particularly in annual cropping situations. In such circumstances, the perceived strategy by loan officers is to reduce the risk of non-performing loans. Such practices on a sector-wide basis can increase the risk of holding significant numbers of non-performing loans, and thus cannot be viewed rationally as being in the credit sector's long-term interest.

Policy makers

The lack of a common view on IPM held by the government agencies responsible for different aspects of national IPM programmes is not conducive to effective implementation. Key decision-makers need to be shown the potential benefits as well as the limitations of IPM in different sectors. Experience with the FAO regional rice programme has shown that this group plays a vital role in influencing action at other institutional levels within national programmes, but on the other hand can impede the progress of IPM.

Another major constraint to IPM, which clearly implies an interdisciplinary, multi-functional approach to solving pest problems, is the manner in which research, extension and technical support services are organized in many countries. There is a clear demarcation of responsibilities between these functions. As a result, the timely flow of information between the different key players, compounded by inter-institutional rivalry, is often impeded. One potential impact of the FAO rice IPM programme could be its ability to bring these different groups together for a common purpose. These institutional constraints need to be recognized in planning for future IPM programmes elsewhere, and decision makers need to be sensitized, again through appropriate training sessions, to the above factors.

This demarcation of responsibilities also means that researchers often have neither the opportunity nor the means to become involved in implementation programmes, or to be familiar with real world problems. Thus scientists who have been generating the knowledge required for IPM may not have a clear understanding of the kind of knowledge that is needed by extension workers or by farmers. Institutional barriers to research scientists in national programmes conducting on-farm research are an important constraint.

International initiatives

The present report is complementary to a recent report prepared by Mackenzie (1989) for the CGIAR Technical Advisory Committee (TAC) on the evaluation of crop protection activities within the international agricultural research centres. The Mackenzie Report recognizes that, with few exceptions, the contribution of the IARCs to crop protection in general and to IPM in particular consists mainly of breeding for host-plant resistance. Whereas this does not detract from the quality of this input, the narrowness of the approach and hence its vulnerability is acknowledged.

The Mackenzie Report recommended that an 'IPM Network' be established amongst plant protection workers at the IARCs; he envisaged that such a network would evolve over a five-year period into a "laboratory without walls". The aim of these initiatives would be to focus attention within the IARCs on other components of IPM than host-plant resistance, and to encourage co-operative programmes amongst the centres on topics of mutual interest. Membership of the proposed network would include representatives from client countries, international agricultural research centres, and appropriate research centres in industrialized countries. There should also be representatives with specific experience in implementing IPM programmes (as opposed to researchers), to ensure that research products are being developed within the context of technologies appropriate for developing countries.

The Mackenzie Report was considered by TAC in 1989/90, as part of a broader consideration of both plant protection research within the CGIAR-supported centres, and the potential role of several other international agricultural research centres not currently supported by the CGIAR. The latter include the International Centre of Insect Physiology and Ecology (ICIPE), the Asian Vegetable Research and Development Center (AVRDC) and the International Network for the Improvement of Banana and Plantain (INIBAP) (*see Current Institutional Structures*, p.29).

Other activities relevant to the present Task Force initiative include current studies by the World Bank on guidelines for IPM and pesticide use within Bank-sponsored projects (*see Multilateral Organizations*, p.31); the status of IPM and opportunities for its implementation in Africa. (Zethner, 1989; Kiss and Meerman, 1991); and the World Bank/ISNAR/ACIAR/AIDAB agricultural biotechnology study which includes some discussion on the future applications from modern biotechnology for pest management (Persley, 1990). The important feasibility study by Wageningen Agricultural University is mentioned above (*see Training*, p.34). Some bilateral development agencies such as GTZ, NRI and USAID are also presently evaluating their present policies and programmes on IPM.

ROLES OF DIFFERENT CONTROLS FOR INSECT PESTS, DISEASES AND WEED MANAGEMENT

This section provides background information on the different methods for control of insect pests, diseases and weeds as a basis for research on, and implementation of IPM. It links in particular to *Technical/Socio-economic activities*, p.16, and *Advantages of the IPM Approach*, p.8. In recognition of the vital significance of weeds in many tropical farming systems, which is often overlooked, there is a specific discussion on weed management.

Significance of different controls

Comparison of controls

In general, the conventional or traditional control components available for an IPM programme are the same for insect pests, diseases and weeds - (i) cultural and mechanical; (ii) biological; (iii) host-plant resistance; and (iv) chemical. In addition, there are novel controls which are specific to a particular kind of pest, for example behavioural or sterilization controls against some insects. Therefore the same set of tools is available for implementing IPM of the different types of pests, but its relative significance varies greatly according to the pest and in relation to particular crop situations. For example, host-plant resistance is of particular significance in plant pathology, notably more so than in entomology, whereas for weeds it is much more limited, and largely confined to resistance to parasitic plants or, in terms of tolerance, the ability of a crop plant to compete with weeds. On the other hand there are situations, as with hessian fly control on wheat and jassid control on cotton, where host-plant resistance to insects is of paramount importance, whilst conversely there are situations where this method is of little or no use in disease control.

The nature of the pest fundamentally affects the significance of different control mechanisms. With rare exceptions (for example the parasitic weed *Striga)*, weeds act primarily by competing with crops, interfering with harvesting and contaminating crop products, whereas diseases and pests cause direct damage. In general, pathogens have a much more intimate relationship with the host than do insect pests. Furthermore, in practical pest control it is often more difficult to determine the pathogens responsible for particular plant diseases than it is to determine the insect pest responsible for equivalent damage. Farmers therefore usually find it easier to recognize insect and weed problems than diseases.

In particular, many soil pathogens are especially difficult to diagnose. This puts greater emphasis on training and on the provision of diagnostic aids for on-farm use by extension workers and farmers. As always, however, it is impossible to generalize - in some circumstances, well-defined symptoms may be all that is needed to diagnose a particular disease and take control action, and it is not always necessary to determine the species responsible. In this respect, some disease symptoms may be more obvious to the farmer than either the cause or symptoms of a particular insect pest.

Fundamentally, the role of different control mechanisms for a pest should be understood in terms of its population dynamics in relation to the dynamics of its host. For example, the ecological conditions for a perennial crop, like those for a climax natural forest, have led to co-evolution of particular kinds of endogenous pests; here the relationships between many pests and their hosts are much more intimate than in annual crops, which are comparable to earlier stages of ecological succession. In the arable system, most of the important pests are capable of quickly exploiting such conditions, in contrast to those which have evolved subtle co-evolutionary relationships with their hosts - this applies particularly to airborne pathogens, as well as to many insects and weeds. It is however necessary to distinguish profound differences between those airborne species which mainly attack aerial plants from those which live in the soil. In many respects, soil pests may be seen as living in relatively stable environments, where the evolving community relationships may contain important elements of biological control which can never be elaborated in the aerial environment. This applies particularly to soil pathogens and nematodes.

The differing strategies in weeds must again be recognized in the context of the overall plant community, whether perennial or annual, and it must also be recognized that weeds do not fit into the category of either an aerial or a soil pest. They compete with the crop in both environments, and their dynamics must be understood in terms of what happens both in the soil (seed banks, root competition, etc.) and above ground.

The above comments indicate how difficult it is to make more than generalized statements about the roles of different control components in an IPM programme for the weeds, pathogens and insects, let alone for other kinds of pests such as vertebrates and nematodes. One factor that most pests have in common is that their importance is exacerbated by certain crop production practices associated with improving crop yield, notably the use of nitrogen fertilizers, which almost always increases the competitiveness of weeds and the susceptibility of the crop to pathogens and insect pests. Many aspects of the drive towards increased yield per unit area of land must therefore be recognized as tending to make all kinds of pest problems worse, so undermining the role of many traditional controls and increasing dependence on pesticides in general.

Role of different IPM control components

Host-plant resistance. This is based on artificially improving the host plant's evolutionary response to pests. While some crop plants do have mechanisms for competing with weeds (generally vegetative structures developed at the expense of yield potential), against pathogens there may be very intimate physiological/biochemical mechanisms of resistance, and against insects some cruder physiological/biochemical mechanisms, as well as mechanical means of deterring insects or enabling such crop plants better to tolerate insect damage.

The strategy of a wild plant is merely to perpetuate itself successfully - this does not depend on maximizing the yield of those plant parts that are of particular value to man. In trying to maximize yield, farmers are therefore asking for infinitely greater defence mechanisms in their crops than the wild plant is able to evolve. In these circumstances, it is remarkable that there are so many examples of effective host-plant resistance in crops, despite their erosion by breeding programmes where resistance has so often been traded for high yield or other characteristics. Host-plant resistance has been most successful against pathogens, yet it is the most fragile of methods used by farmers for disease control. The kind of resistance most commonly incorporated by conventional breeding techniques has been based on single genes (known as vertical resistance). At times, the co-evolution of the pathogen has been slowed by manipulation of selection pressure to prolong host-plant resistance. However, boom-and-bust cycles in host-plant resistance have commonly occurred, even in the more successful examples of the Green Revolution. Much research is now aimed at developing more durable horizontal resistance, but as yet its impact has been minimal. Because host-plant resistance so dictates the system within which a pathogen operates, more effort is needed to integrate it as a component of IPM, in place of the sole reliance on resistance practised in many countries.

For insects, there are fewer examples of successful host-plant resistance, although in some respects a wider range of options is available, based on resistance mechanisms which deter or tolerate pests, as opposed to the single-gene resistance that predominates in disease resistance. Resistance to weeds associated with competitive ability was perhaps the first control mechanism lost in the breeding of high-yielding varieties, where the prime effect was to trade vegetative growth for seed production in all cereal breeding programmes.

In conclusion, host-plant resistance must be recognized as the fundamental method of control against diseases and insect pests, in particular because it does not involve on-field farmer labour or decision-making. This is the reason for the emphasis on breeding programmes in all the international agricultural research centres. It is now recognized that over-reliance on host-plant resistance is seriously undermining the value of this control method, as it intensifies the selection processes in pests to overcome such resistance. There are abundant examples of this, which amply justify the need for an IPM approach to disease and insect control, as well as reconsideration of breeding programmes in relation to the re-establishment of qualities that make some crops more competitive with weeds.

In an IPM approach, it is vital to recognize that absolute resistance, for example immunity, is not necessarily the goal; in fact it may well be the wrong goal because of the likelihood of resistance breaking down. Small degrees of resistance can make other components of the IPM armoury much more effective than would be expected from purely additive effects. With weeds too, in some circumstances, the ability of a crop plant to tolerate some weed competition at certain stages of crop growth could give greater flexibility to the farmer in his other weed control practices.

Cultural and mechanical controls. These have been the cornerstones of many pest control practices, particularly in arable agriculture throughout the world. They remain the single most widely used control method in both industrialized and developing countries, even though the use of many such controls has been eroded through the substitution of pesticides.

Perhaps the most powerful are those controls based on crop patterning in time and space, which in various ways dislocate the life cycle of a wide range of weed, pathogen and insect species. Cultural controls are particularly important as part of the agro-ecosystems approach (*see The Agro-ecosystem Approach,* p.10). In the context of integration with host-plant resistance, the patterning of different varieties of a crop in a way that minimizes the spread of particular strains of a pathogen is a vital form of integration which needs to be developed much more widely, particularly in cereal monocultures. Various forms of mixed cropping and intercropping also minimize the spread of airborne pathogens and insects.

Crop rotation has been the basis for control of soil-borne pathogens, nematodes and some insects, as well as of weeds, for many centuries. The crop pattern can have important effects on insects, for example by diverting pests away from the crop at risk to another, less susceptible crop; and also by enhancing some biological controls. Conversely, inappropriate crop patterning can exacerbate pest problems - this has become much more serious with the intensification of agriculture (*see The Agro-ecosystem Approach,* p.10). Examples include the continuous cropping of irrigated rice, the intensification of rotations, and the replacement of certain non-host crops by those crops which are considered more remunerative.

Until the advent of herbicides, cultural practices through crop rotation and mechanical or hand weeding were virtually the only control mechanism available against weeds. They remain vitally important, but much more serious consideration is needed to establish how they can be integrated with judicious herbicide use, in order to help remove the single most important constraint to crop production in many dry-land farming systems in developing countries: the timely availability of labour. This is discussed in more detail in *Weed Management in Cropping Systems* below.

In conclusion, much more attention must be paid to the whole range of cultural controls, especially as they have so often tended to be disregarded because their value has not been appreciated, or because it has seemed easier or more effective to replace them with pesticides.

Biological controls. These have proved particularly important for insect pests, the most successful examples being in the control of an exotic pest which becomes established on a crop in the absence of its indigenous natural enemies. Identification of the natural enemies, and their reintroduction to the area penetrated by the pest species, may then result in a spectacular reduction of damage due to the pest. Many examples of such successes now exist, one of the most recent being the control of the cassava mealybug of Africa by natural enemies introduced from Latin America. It is of course essential that opportunities for such 'classical' biocontrol procedures continue to be recognized, and support given for the necessary research both to identify natural enemies of the exotic pest, and introduce them safely through appropriate quarantine to the area where the pest is causing damage.

The value of biological control is also demonstrated by the resurgence phenomena associated with the use of broad-spectrum insecticides, which kill not only the pest, but also its natural enemies. If the pest is one that re-establishes itself more quickly than its natural enemies, a single treatment of a crop with the pesticide will be followed by a more intensive attack, requiring a further spray, and creating an even greater problem. The recognition of resurgence phenomena when wide-spectrum insecticides have been used to control rice pests has enabled more appropriate pest control methods to be introduced (Teng, 1990).

Proper understanding of the management of indigenous natural enemies of pests is one area of research which could lead to far more environmentally desirable procedures for pest management. Biological control by indigenous natural enemies of pests is not only environmentally desirable, but is generally compatible with other control procedures, such as cultural controls, host-plant resistance, and proper use of pesticides.

While biological control has had its greatest successes with insect pests, it also has potential for the control of weeds and pathogens. In weed control, it is not necessary to kill the weed but merely to reduce its competitiveness; hence weed pathogens can be effective control agents. The introduction of insect pests of water weeds has also resulted in spectacularly successful control. However, such levels of success are less likely in arable systems, although more subtle effects may still contribute to control within an integrated approach.

Our understanding of the biological control of pathogens is still in its infancy. There is good evidence that competitors have a major impact on rust pathogens, and cultural controls often work effectively because of their influence on soil-borne pathogens. Retention and enhancement of natural biological controls against most pests must be a major factor in desirably safe and sustainable pest management practices. Much research needs to be done to enable them to achieve their full potential.

Chemical controls. The vast array of pesticides now available, firstly insecticides and then herbicides and fungicides, has transformed pest management. Their very success has led to well-known serious misuses and to a damaging reputation, the context in which IPM developed. However, this has sometimes led to over-reaction: the actual and potential value of chemical pesticides must be recognized, both for food production and for disease control. We must accept that many pesticides have an important role in the IPM armoury. The key question is how to use them rationally, as a component of IPM, as and when necessary. At present there are no new alternatives. Moreover, some emerging technologies such as those based on genetic engineering and the use of pathogens may have more serious disadvantages for man and the environment than many currently used synthetic pesticides.

Certain insecticides must be seen as environmentally hazardous through their toxic effects on man and on various biological systems. Many of the worst have been phased out; however there are ironical situations in some countries, whereby some pesticides highly toxic to man are still being recommended, while relatively safe alternatives have been banned because they are harmful to natural enemies of pests, such as the brown planthopper. In general, with a few important exceptions, fungicides and herbicides are less environmentally damaging - some have outstanding properties of selectivity of the kind possessed by very few insecticides. Although herbicides may prove to have more subtle deleterious effects than are at present appreciated, they and many fungicides appear to be more specific than most insecticides.

In the foreseeable future, pesticides must be recognized as essential components of many IPM practices. In many cases they are being excessively used or badly applied, and one of the main priorities, often the first priority of an IPM programme, is their rational use. Indeed, the first step in an IPM programme for crops such as rice, as well as other crops that are currently much treated with pesticides, is to use them safely and minimally as demonstrated by the FAO rice programme in southern and South-East Asia (Kenmore, 1990). Crops such as cotton, along with many other commercial cash crops, are also being excessively treated with pesticides, although it must be recognized that in some situations where pest control practices are undeveloped, there will be a case for judicious use of more pesticides, for control of *Striga*, for example, and of other weeds which at present are a major constraint to crop production.

Scheduled spraying of pesticides is still the most common method of application, especially for fungicides. Techniques to rationalize use have been developed, but not widely used. Prediction systems, simple decision aids, thresholds and decision charts have been developed, as in the South-East Asian rice programme (Kenmore, 1990) and for other crops such as cotton. In Japan and Korea, large-area pest surveillance systems are in operation with computer-based prediction models for diseases of rice. These have been shown to enable early warning of economic loss and development of new pathogen races. To aid in disease management, there are improved diagnostic tools for pathogens and diseases based on modern biotechnology, for example, monoclonal antibodies. Soon these may find applications in high-value cash crops in developing countries.

The above comments indicate the vital role of the traditional control components for IPM implementation programmes. Such controls are fundamental to any pest management system, though it is disappointing that other kinds of control have so far made relatively little impact on the pest management scene. At present, we must therefore rely heavily on the four basic methods listed above, and on improvements in their integration. The IPM status reviews above exemplify opportunities for such improved implementation in different systems, ranging from arable to perennial and from subsistence to intensively grown crops.

Weed management in cropping systems

Weeds are ubiquitous: they are present in virtually every crop and cropping system from subsistence farms to commercial estates. Estimated crop losses due to weeds in developing countries are of the order of 25-30% of potential yield. However, substantial evidence suggests that the presence of weeds in fields cannot automatically be judged as damaging and in need of immediate control. In fact, crop-weed interactions vary according to plant species, environmental factors and management practices, which in turn vary according to the cultural traditions, social organization, and economic forces of agricultural systems.

Although weeds are important pests in their own right, they are also hosts of insects, diseases and other pests, and of the natural enemies of these pests. Weed management therefore has direct and indirect effects, with both positive and negative scope for integrating weed control with insect and disease management, although in practice the proven strategies are limited. There are however ample opportunities for the integration of weed management with crop production and farming systems (e.g. timing of cultivations, crop spacing, rotations, intercropping, crop variety, placement of fertilizer, timing and depth of flood irrigation, etc.). Many of these techniques are conventional practices, but there is scope for considerable improvement without recourse to inappropriate weed management technologies.

Weeds and farmers' decisions

Weed management for the majority of small-scale farmers is one of their most time-consuming activities; land preparation and subsequent hand-weeding commonly take 50% or more of the total time required to produce annual crops. Work requires time (his or her own, the family's, or hired); energy (the availability of which is determined by physical strength, endurance, health and diet); and perhaps the financial or other resources to hire labour. Hence the opportunity costs must be added to the costs of crop loss and of control.

Weeds can strongly influence what farmers choose to do with their land; some examples are listed below.

- *Whether to abandon cropped land* because of excessive weed infestations. It can be easier to open up short- or long-term bush/tree fallows than to prepare land with severe infestations of weeds. Fallows may be utilized by farmers to 'rehabilitate' weed-infested land. Weeds that have forced farmers to abandon land include, for example, *Imperata cylindrica* and *Striga* species.

- *Whether to clear fallow land.* Some weeds, such as the rhizomatous perennial grass *Imperata cylindrica,* are so difficult to control that the effort is not justified by subsequent crop yields.

- *The area of land that can be managed.* If too much land is prepared and planted, insufficient labour may be available to weed it. Despite this, farmers who are not constrained by the availability of land generally tend to manage a large area badly rather than a small area well.

- *Crops to be grown.* Some crops may be so badly infested with *Striga* or other parasitic weeds that non-susceptible species must be grown instead, if possible. Intercrops may be used to suppress weed growth more effectively than sole crops. Crop spacings and varieties may be selected for ease of weeding rather than for agronomic reasons. The timing of sowing certain crops may not be optimal for yield or for reducing susceptibility to other pests because of delays caused by the demands of weed control.

- *When to weed the crop.* This can only be done adequately at a time when labour is available, but this may not coincide with the optimum time for minimizing weed competition.

It is apparent that weeds, apart from their direct effect on crops, profoundly affect what farmers do. Improving weed management, particularly by alleviating labour constraints, has repercussions for all aspects of crop production, the sustainability of cropping systems, and the social conditions of farming families.

Farmers' options for weed management

Farmers have many more options for the control of weeds than for other groups of pests. They include mechanical control (hand-pulling, hand-cultivation, animal-drawn cultivation, slashing, etc.); cultural techniques (crop spacing, planting time, rotation, ground covers, etc.); herbicides; and in a few cases, biological control. Weed control, whether carried out consciously by farmers or not, is often achieved by a combination of crop production practices and specific weed management activities. Integrated weed and crop management is not a new concept, and in theory, improved techniques and technology need not be alien to farmers. However farmers tend to be conservative and reluctant to change traditional practices, especially if they perceive risks.

Farmers' weed management options are also determined by what they can afford (for example herbicides, hired labour); what is available (for example stores that sell cultivators, sprayers); their knowledge (for example, how to use herbicides); and the availability of advice and information. Very often, these are severe constraints to improved weed management.

Relevance of herbicides to small-scale farmers

Herbicides considerably reduce the time required to weed crops and, for some weeds, give better control than can be achieved by traditional methods. Farmers able to use herbicides gain the time and ability to crop more land, more efficiently and at more appropriate times.

Herbicides, by definition, kill plants. It is by selectively controlling weeds without harming crops that herbicides can be employed. There are several ways of achieving selectivity, most of which require precision in terms of dose, timing and placement. Herbicides differ in their requirements for achieving selectivity, and any deviation from recommended practice for their use can damage crops or fail to achieve the desired level of control. Whilst the majority of farmers in developed countries have the capability to use herbicides safely and effectively, this is often not the case in developing countries. It is therefore legitimate to question whether herbicide use should be encouraged in developing countries. The answer must be a qualified yes - it would be wrong to deprive the developing countries of technology that has done so much to revolutionize farming in the developed world.

With training, advice, information, equipment, protective clothing (where necessary), and the ability to acquire herbicides at an affordable price, it should be possible for farmers in developing countries to employ chemical weed control. Herbicides, with a few notable exceptions, are generally less toxic to man and livestock than other pesticides, and their use need not be constrained if adequate safety precautions are taken.

For progress to be made in introducing herbicides to small-scale farmers, it is necessary that they be integrated into existing crop- and weed-management systems. It is neither necessary nor desirable to substitute chemical control for other methods. For example, it is possible to combine herbicides with supplementary hand-weeding to overcome labour constraints at the beginning of the season. Band applications of herbicides over the crop row could minimize weed competition until the farmer has time to remove weeds from between the rows. The efficacy and practicality of these and other possibilities need to be determined in practice at the farm level. Most research on herbicide threshold levels has been carried out solely on crop yield loss criteria—not with a full cost-benefit approach. Consequently, threshold levels have often been set too low.

State of knowledge

There is considerable information available on weed control, including optimum times for weeding; optimum doses of herbicides to achieve selective weed control; and the most efficient hand tools for a particular crop and location. Although there are many gaps in this knowledge, the application of known technology by small-scale farmers could substantially improve their management of weeds. The question therefore arises: why do farmers not use improved weed management? The answers are many and varied, but they reveal that we lack the ability to transfer the technology to the farmers. This requires, amongst other things, institutions to help the farmers (e.g. a good extension service) and an understanding of the social and economic factors which dictate what farmers can do (*see Farmers' Decision Models for IPM Implementation,* p.11).

Potential problems with 'improved' weed management

Unlike most pests, weeds are usually problematic as a mixed flora rather than as individual species. It would not be unusual for a tropical smallholding to have as many as 20 or more weed species in a single field, none of which has a significant effect on the crop. However, competition from the combined species can be dramatic. Any crop- or weed-management system will favour some species whilst discouraging others, and this can be exploited as a method of weed management by rotating crops. Unfortunately, 'improved' management of crops may exacerbate weed problems, for example:

- *fertilizers* can benefit weeds as well as crops and have been known to reduce crop yields by increasing the growth of weeds;

- *high-yielding crop varieties* may require higher inputs, especially fertilizers, which encourage weed growth;

- *crop varieties* bred for their resistance to pests or to lodging may have habits and canopy structures which are less competitive with weeds than 'unimproved' varieties;

- *herbicides* remove susceptible species and allow the proliferation of tolerant weeds. For example, the repeated use of atrazine in maize has created problems with tolerant grass weeds; paraquat as a sole herbicide used for minimum or zero tillage encourages the dominance of perennial grasses and sedges. Already herbicide resistance has developed in some weed species. Many of these problems are avoidable, but the solutions depend on integrating the various systems of managing crops.

In conclusion, it is recommended that much more attention should be paid to weeds and weed control in future IPM programmes in the tropics.

Constraints on IPM Implementation

TECHNICAL/SOCIO-ECONOMIC CONSTRAINTS

General

In this section some of the constraints to wider adoption of IPM are discussed. Throughout, the knowledge process which the constraint addresses will also be noted, that is whether the type of constraint is at the level of knowledge generation (research); synthesis (research/technical services); adaptation (technical services/extension); dissemination (extension); or adoption (farmer).

Institutional constraints

The lack of a common view on the objectives and operational aspects of IPM by the government agencies responsible for different aspects of a national IPM programme, is a constraint to more effective implementation.

IPM requires an interdisciplinary, multi-functional approach to solving pest problems. The manner in which research, extension and technical support services are currently organized in many developing countries then becomes a major factor in developing and implementing IPM programmes. In Thailand, Sri-Arunotai (1988) has described the clear demarcation in responsibilities between these elements. As a result, the timely flow of information between the different key players is less than desirable, and this is exacerbated by inter-institutional rivalry. One reason for the impact of the FAO Intercountry Rice IPC programme is its ability, as an outsider, to bring these different groups together for a common purpose at no perceived threat to the individual groups. This institutional constraint needs to be recognized in planning for future IPM programmes elsewhere.

Demarcation of responsibilities also means that the scientists who have generated the knowledge required for IPM may not have a clear understanding of the kind of knowledge needed by extension workers or by farmers. Institutional barriers to research scientists in national programmes conducting on-farm research in developing countries are real, and need to be addressed.

Informational constraints

The lack of IPM information which could be used by farmers and by extension workers is still a major constraint in many countries. More important is the nature of the material available, as Escalada and Kenmore (1988) have shown (*see Training,* p.34).

Most countries with national IPM programmes feel that, while the individual control techniques for plant protection are relatively well known, little knowledge is available on using these in an integrated fashion under farm conditions (Consortium for International Crop Protection, 1988). Also, although the philosophy behind IPM has an ecological basis, the ecological information required to understand and design IPM programmes for insect pests and diseases of crops is unavailable in many countries. Concern over the lack of ecological information on pests has been expressed at many regional workshops (Teng and Heong, 1988) and recently IRRI, in its five-year plan for 1990-95, has given high priority to meeting this challenge.

The lack of training materials, curricula and experienced teachers on the principles and practice of IPM is another problem in many developing countries. In Indonesia, for example, with the expressed intention of the government to increase the percentage of IPM adoption, this is now the limiting factor to implementation.

Technological constraints

Suitable technologies for IPM, taking account of the receptivity of different farmer groups, are still not widely available. In the FAO Intercountry Rice IPC programme, the most useful technology has been that associated with improved problem diagnosis, that is training farmers to recognize pests and natural enemies. There has been only limited use of thresholds, mostly for insects. Many of the techniques developed by researchers are presently not useful to farmers, but admittedly do have future potential. Related to the issue of appropriate technology is the lack, in many developing countries, of a smooth and timely flow of information from researcher to farmer; in India, an attempt has been made to rectify this through the ICAR operational research projects initiated by M. S. Swaminathan, who also started a 'lab-to-land' programme (Pal, 1979; Perkash, 1979; Singh, 1979; Naide *et al.*, 1983; Mishru *et al.*, 1986).

More constraining than the availability of IPM technology itself, is the lack of facilities and support services for extension personnel to do their work. Many countries do not have functional extension IPM programmes because the staff concerned have no means to travel to farms or to set up field demonstrations. Unless national programmes are convinced of the need for IPM, and are willing to put their own resources into practice, any impact generated by external assistance will be transitory.

A problem related to the question of appropriate technology is that few national programmes have scientists capable of generating the IPM technology themselves. The majority of plant protection scientists in the tropics have strong traditional skills such as diagnosis, and much knowledge about unilateral control methods; few have been exposed to contemporary knowledge on IPM. Developing technology for knowledge simplification is not an easy process and requires a great deal of experience and confidence on the part of researchers.

Even if technology were available, there are few guidelines for its application. IPM is not a technology package; rather it resembles a technology basket, from which intelligent decisions have to be made on what techniques are suitable for a certain situation. A major constraint is therefore lack of knowledge on how technology generated at one location can be applied elsewhere.

Sociological constraints

The conditioning of most farmers by industry or by public sector workers towards unilateral approaches to pest control is a real problem, especially with insecticides. Many have not been taught or encouraged to 'think' IPM. Chemical pesticides are presented as highly effective and simple to apply: the constraint is in the attitude of a relatively large proportion of farmers and extension workers, who still favour technology that is simple to use.

In Thailand, the limited educational background of farmers was considered as a major constraint by researchers in IPM implementation (Teng *et al.*, 1990), although it was felt that, with the appropriate involvement of farmers in technology testing, receptiveness to IPM would be higher. This view is not supported by data from the Philippines, which show that even farmers with limited educational backgrounds are able to understand and apply thresholds for insects, for example (Kenmore *et al.*, 1987).

In an important paper, Goodell (1984) asked whether the scientific community really wants IPM to work, and if so, why more effort is not put into understanding the farmer's decision process and his information needs. Her work has shown that the training and visit system, even if actively implemented, only reaches a very small proportion of farmers. This is also the case with the demonstration plot and group meetings used by the FAO regional programme. The constraint therefore appears to be in generating the right message about IPM for the relevant farmer group.

Economic constraints

The issue of economic risk and positive returns from using IPM rather than conventional, scheduled practices is one that appears to be present in the minds of many extension workers and farmers. While there are considerable research and demonstration-plot data to show that IPM is workable (Kenmore, 1989; Smith *et al.*, 1989), there is a lingering doubt as to its reliability under all circumstances. This is partly due to the need for IPM decisions to be tailored to the prevailing conditions, in contrast with a 'package' which removes apparent uncertainty from the decision process. The uncertainty constraint could be removed by improved knowledge and better education programmes. A major effort on this is under way by IRRI and the FAO regional programme.

National IPM programmes definitely pay for themselves in terms of savings on resource inputs for production. However, IPM must be viewed as an investment and, as with other forms of investment, requires an outlay. Although several countries have made IPM the basis of their national plant protection policy and programme, and provided the financial resources to implement it, many others have done neither. A major constraint, even if IPM is adopted in principle, is therefore the funding for the research, extension and farmer training needed for an accelerated programme.

Political constraints

The relatively low status of plant protection workers in the administrative hierarchy, especially those in extension, was considered by Teoh and Ooi (1986) to be a major constraint to general improvements in plant protection. Associated with the above are the morale and financial standing of these workers. There are many examples of workers who, on paper, have impressive programmes but in practice do not have the funds to travel and execute those programmes (*see Crop Protection Technical Services Personnel*, p.35). Such resources are often not among those available from external funding agencies, and a more logical approach may be to generate the right policy environment, and local political support and commitment.

Environmentally conscious groups such as PAN International have highlighted the inter-relationships between the different sectors involved in the pesticide trade, and questioned whether these are not the major constraint to any attempt to reduce pesticide use. There are many vested interests associated with the pesticide industry. This raises issues, many of which could be addressed by an explicit government policy on IPM.

The role of pesticide subsidies in IPM was discussed in the Introduction. While pesticide subsidies continue, and if government-provided credit for crop production is tied to these, they become a major constraint to farmers' acceptance of IPM, as seen in the Philippines and Indonesia. Removal of pesticide subsidies will therefore be a key act in IPM implementation.

Others

The influence of the agrochemical industry was cited in several questionnaire replies as a major factor to contend with in efforts to implement IPM. There appears to be a direct conflict between industry's objective of more sales, and the IPM message of rational pesticide use, in the eyes of farmers. This points to the need for private industry and public sector extension to work in a more complementary manner.

Specific constraints identified from surveys

The following section provides information on constraints specifically identified during the mail survey for illustrative crops/pest problems (*see* Iles, 1990; Iles and Sweetmore, 1991).

Rice. A major problem in many countries is the lack of a common view on the objectives for IPM by the government agencies responsible for different aspects of a national programme. The demarcation of responsibilities also means that there is a gap between what scientists consider is knowledge required for IPM, and what is actually required or accepted by extension workers or by farmers. Institutional barriers to research scientists in national programmes conducting on-farm research in Asia are real and need to be addressed. The shortage of IPM information or technology that can be used by farmers and by extension workers is still a major constraint in many countries. Related to this is the lack of teaching material for farmers, extensionists, researchers and teachers. Most countries with national IPM programmes feel that, while the individual control techniques for rice plant protection are relatively well known, little knowledge is available on their use in an integrated fashion under farm conditions.

Vegetables. Constraints occur at all levels: the absence of knowledge; physical technology; and institutional, economic and sociological factors are all involved. Little IPM technology is currently available for farmers. Host-plant resistance, commonly a first step in transferring IPM technology, is not available in many crops for many key pests. Pesticides are presently the main solution to pest problems. Biological control research is still in its infancy, except for efforts on diamondback moth (*Plutella xylostella*) on crucifers, and a few other pests.

Millet. The only constraint that is not operating on IPM implementation is agronomic research; substantial basic knowledge about IPM strategies has been developed, mainly through on-station experimentation and on-farm research. However, IPM technologies which are appropriate to the conditions of resource-poor farmers have not been developed. Additional research on the socio-economic context of millet-farming systems is needed to identify the types of IPM inputs most likely to be effective. Complementary studies on pest management strategies already used by farmers are needed: for example, crop varieties used in rotation, planting dates, etc. The links between research and extension are extremely weak. Furthermore, in IPM projects supported by foreign aid agencies, the major constraint is the short duration of projects: long-term project commitments are needed in order to be effective.

***Striga*.** Whilst much is known about some controls, research both inside and outside Africa is required to find reliable and appropriate methods of controlling *Striga*. Recommendations from six *Striga* workshops were summarized at a meeting held in Banjul, Gambia in December 1988 (FAO, 1989). Comprehensive recommendations were also made at an Ibadan *Striga* workshop in 1990, which proposed basic research, resistance breeding programmes, adaptive and applied research, and information networking (FAO, 1990). The lack of adequate resources over a long period to support these efforts seems to be the major constraint to implementation of IPM on *Striga*.

Cocoa. One major constraint is the scarcity of institutions to foster work on cocoa, except in Ghana and Nigeria, in contrast to most other comparable cash crops. Much research is therefore fragmented and confined to commercial organizations and small projects in universities, for example. In general, pest management practices seem to have deteriorated in parts of West Africa and the Americas, associated with decreased support, including that for the institutes in Ghana and Nigeria. In western Malaysia, despite available knowledge from large (plantation research, the great majority of farmers (possessing about half of the total cocoa area) receive little help from extension services, and many are ignorant of the pests and of possible controls.

Cotton. A major constraint is the absence of an international institution dedicated to work on cotton. Zimbabwe and Malawi have good national research stations for cotton, though these have funding problems. In Zimbabwe extension is weak for small-scale farmers, partly because small-scale cotton growing is increasing so rapidly. It is evident that institutional and other problems are more serious elsewhere, with special difficulties in the Sudan, and there is often too much dependence on commercial firms for advice rather than on the government, where official advice is lacking. Yet in Pakistan, production has notably increased since government control of pest management ceased five years ago. Except perhaps in Zimbabwe and Malawi, there does not appear to have been sufficient farmer involvement in development of pest management practices.

Soybean. IPM is adopted in the south of Brazil, but not elsewhere. This appears to be associated with institutional constraints in the north, notably the extension services. Adoption has also been difficult in central Brazil, where large farms are routinely sprayed from the air. More appropriate technology is needed for this region, including more appropriate sampling procedures. Adaptive research is needed for weed control methods to be translated from the south, where they are best developed. In general, more basic research is needed on weeds, for example on their competitiveness, and also on possible thresholds for herbicide application. Additionally, a more aggressive extension approach is needed at the farm level, as chemical salesmen tend to negate decreases in insecticide use. Work is needed on some new insect pests causing problems in central Brazil.

Maize. In Latin America, there have been difficulties in using complicated methods, yet it is evident that similar methods have been accepted and readily shared by farmers. There are technological and informational constraints; also limitations in more basic and in adaptive research. It seems evident from the questionnaire response that much could be done by a strengthened programme of IPM implementation based on the approach of some other successes, for example the rice programme. Similar constraints exist in Nicaragua, especially since the termination of the FAO programme. Again, there are available IPM techniques, justifying a major implementation programme.

Potato. Apart from heavy competition from the pesticide industry, the most important limitation is lack of potato tuberworm pheromones to meet the demand for successful monitoring and control. The extension service also requires an increase of properly trained and equipped staff. The transfer of this programme to the rest of Central America will require external support.

Pastures. There are no major limitations. Although the progress achieved has been obvious, IPM must be expanded through intensive training of technical and extension staff, as well as farmers. Improvement of laboratory production techniques for fungal agents used against major pests; the establishment of more production units; and the implementation of proper marketing techniques will permit a generalized adoption of the technique, not only in the rest of the Costa Rican cattle growing areas, but perhaps in the other countries of Central America and the Caribbean. A small investment of 'seed money' is required from external donors to support the expansion of this effective IPM programme.

Wheat. The recent introduction of the Russian cereal aphid *Diuraphis noxia* is a serious threat to the stable wheat ecosystems of the South American zone countries. International support is urgently required for the search for, introduction and colonization of its natural enemies. Prompt international co-operation is of paramount importance to solve this new problem.

INSTITUTIONAL CONSTRAINTS

Experience has shown that the development of effective research components and of appropriate procedures for implementing IPM at the farmer level is a difficult task. Even after 20 years of research, there are not many examples of successful adoption of IPM in the industrialized countries, and even fewer in the developing world. In part, this reflects the complexity of IPM, which is compounded in the developing countries of the tropics where resource-poor farmers practise complex farming systems.

It must be acknowledged that the various institutions involved in research, development and implementation of IPM in developing countries have made a tremendous effort and have attempted various strategies during the last 20 years; however, success has been limited. The principal constraints are judged to be in the seven following areas.

- **Lack of a policy commitment to IPM.** Both the national programmes of developing countries and the donor agencies have lacked a policy commitment to IPM in the context of national economic planning and agricultural development. This has resulted in a low priority for IPM from national programmes and donors alike. Moreover, most of the resources already invested in IPM have unfortunately not had the significant impact promised by its promoters.

- **Lack of a global forum.** There is no institution or organization that can take a holistic view of IPM in facilitating and integrating, but not co-ordinating, the activities of the many agencies involved in IPM research, development and implementation. This means that there is a serious weakness in promotion and mobilization of resources for implementing IPM programmes in developing countries.

- **Fragmentation of effort and activities.** Fragmentation between disciplines, between research, extension and implementation, and between institutes - all of which lead to a lack of institutional integration - is a principal constraint.

- **Inappropriate research.** The usual approach, with a few exceptions, has been the traditional top-down research that does not address the real needs of farmers, who eventually are the end-users, and who elect to adopt or reject the technology based on its appropriateness.

- **Inadequate monitoring, evaluating and learning from experience.** No organization has a mandate specifically to ensure that maximum benefit is derived from past experience, by documenting successes and failures, and by sharing this information with the other organizations involved in the research and implementation of IPM in developing countries.

- **Inadequate training materials and programmes.** The interdisciplinary nature of IPM makes training a critical need for both research and implementation, as conventional training emphasizes a disciplinary approach, whereas the needs of IPM are diametrically opposed. IPM field programmes (successful and failed) can generate the best training materials.

- **Lack of contact between agencies already implementing IPM.** FAO, assisted by the FAO/UNEP Panel of Experts on Integrated Pest Control, has for the past 20 years pioneered the IPM approach and has been responsible for local and regional IPM programmes on cotton and rice in particular. However, there is no formal mechanism for the various institutions involved in IPM to share information, to benefit from common guidelines based on successful operational strategies, and to engage in joint activities. No institution has been mandated to overview IPM activities, to facilitate the exchange of information and to provide guidance, based on past experience, on the research, development and implementation of IPM, including policy issues in the developing countries. This is more a role for a facilitator than for an executor. The above section on institutional constraints is further elaborated by James (1990).

Opportunities for Implementing IPM

The analysis of illustrative crops, control methods and constraints in the previous three sections underlines the importance of further donor support and national programme commitment to IPM. It has also shown that IPM is an approach that, when practised, can have demonstrable benefits to farmers, developing nations, donor agencies and the wider environment. Several points arise from the above analyses.

- IPM implementation requires a substantive commitment on the part of national governments; this must be matched by appropriately designed projects funded by the donor agencies (for example, the successful FAO rice programme in southern and South-East Asia).

- A basic infrastructure for plant protection needs to exist before IPM can be implemented; this includes human resources at various levels, equipment, vehicles and local extension support (for example, there is a lack of plant protection infrastructure in many West African countries).

- IPM programme design must ensure that the technology meets the needs and capabilities of farmer groups, and proper definition of the problems, and of the potential IPM environment, is critical before a project is designed or executed (for example, the knowledge, aptitude and practice surveys conducted by national rice IPM programmes in South-East Asia).

- Current information must be available for IPM implementation, while future knowledge must be selectively generated through research that meets implementation needs; the lack of communication mechanisms between research and extension, and the weakness of interdisciplinary research, must be addressed (for example, the present research and extension systems in most national programmes).

Opportunities exist for donor agencies to facilitate the above either directly or indirectly.

Rice IPM has served as an example of what can be done in developing countries to implement the concept over large areas by influencing a large rural population. Even with rice, however, the job is by no means complete (Teng, 1990).

In the preceding sections, an analysis was made of different aspects of IPM, starting from the environment in which IPM is practised and ending with a discussion on constraints to its implementation. IPM is predominantly a knowledge-driven technology, even though some physical technology is used; its implementation relies heavily on the human element, and is thus influenced by the high variability in the ability to use technology inherent in diverse social groups. It is also obvious that IPM technology will be different for the same crop grown in different ecosystems. While some scientists have argued that enough knowledge is available to implement the concept, albeit in a rudimentary form, others feel that there is too little working technology for farmers to use. Response to the above must recognize that IPM can be implemented with different degrees of sophistication. The FAO Intercountry Rice IPM programme in southern and South-East Asia, for example, utilized a relatively small number of tools to have IPM adopted as an approach by farmers, extension workers and policy makers alike. What is impressive about this programme is its ability to make use of several pest outbreaks to effect policy changes substantively, and to convert farmers from pesticide dependency to a more open-minded attitude about pest control. The case study (Teng, 1990) showed that the availability of scientific knowledge and enthusiasm is not enough to convince farmers and government officials of the need for change. Viable alternatives, with clear benefits, need to be demonstrated in situations.

REQUIREMENTS FOR IPM IMPLEMENTATION

To accelerate IPM implementation at the national programme level needs certain conditions to be met and certain actions to be taken. These include:

- *government support*, in the form of policies that favour IPM, such as policies to reduce pesticide subsidies;

- *government action*, such as monetary support, to strengthen the extension, research and technical services required for IPM implementation;

- *adequate institutional infrastructure*, such as the basic elements of a plant protection system incorporating research and development, diagnostic services, regulatory services and training;

- *scientists* trained in IPM problem analysis and able to generate the locality-adapted technology for IPM;

- *crop protection specialists and extensionists* able to conduct large-scale implementation programmes;

- *farmers* sensitized to the reliability of IPM and provided with incentives to adopt it;

- *consumers* who are conscious of the hazards of over-dependence in their food production system on unilateral pest control, and who are willing to support policies and action aimed at giving farmers options such as credit for alternative practices.

At the international level, similar conditions must exist, among which are:

- *bilateral/multilateral agencies* willing to co-operate in funding IPM implementation programmes;

- *international or regional research organizations* willing to redefine their agendas and generate knowledge that national programmes can use in a timely manner;

- *national programmes* that are willing to dedicate resources to implement IPM, and willing to work with bilateral/multilateral agencies and international agricultural research centres to ensure expeditious sharing of knowledge on comparable ecosystems.

Ultimately, IPM is implemented by national programmes, working in collaboration with or independently of external expertise. At best, bilateral, multilateral and international agencies can provide the catalytic resources for a short-term effort to influence representative samples of farmers.

OPPORTUNITIES FOR ACCELERATING IPM IMPLEMENTATION

General recommendations

This report demonstrates the wide variation between countries in structures available to facilitate (or impede) the adoption of IPM projects and programmes. Before taking steps towards a more 'integrated' approach, each country needs to examine the existing structures, identify gaps and inconsistencies, and then undertake modifications. There are, however, a number of factors which occur frequently, and should be considered more likely to require attention.

- IPM projects need to involve farmers in developing a range of possible technologies. This is particularly important where the cropping system is complex and farmers have previously practised only traditional methods of pest management. Once farmers have had a minimum of exposure to new technologies that offer clear benefits, they are often quite prepared to accommodate these methods into their traditional agricultural practices, either in whole or in part.

- Research recommendations need to recognize the variations in farmers' management potential and the extent to which they are already achieving that potential. A useful distinction can be made between a farmer with unused potential, who is in need of advice or training, and a farmer who is already fulfilling the potential of his/her immediate resources. In the latter case, the farmer is a prime candidate for new technologies or particular services that will facilitate a higher level of productivity.

- When deciding on the potential for bringing about improvements in a given pest-affected farming situation, it is necessary first to determine the current status and the individual farmer's inherent management potential. When identifying a farmer's current status, it may be useful to think in terms of gaps of information (Norton, 1987). Starting from the farmer's current position, is there potential for improvement? Are technologies available for the farmer to use? Is he/she adopting them? If not, assuming that the technologies are seemingly appropriate to the individual's circumstances, is the farmer then unable to use them for some reason, or is he/she unaware that they exist? If unable to use them, the farmer would appear to need training; if unaware, then the information needs to be disseminated. This approach has been successfully used for small-scale irrigated rice in South-East Asia (*see Rice*, p.16).

- If the technology is not appropriate, it may be that insufficient research has been carried out, or that the output of the research has not been adequately interpreted to fit the farmer's circumstances.

- The value of applied research must be assessed by the extent to which its recommendations are adopted by farmers. By inference therefore, the researcher must recognize, and base his/her planning and research on, the key components identified in the model. As we are dealing essentially with the application of research to meet the needs of low-income and often resource-poor farmers, it is vital that it should be 'demand-led' rather than 'science-driven'. The ability to achieve this satisfactorily depends on two fundamental, inter-related attributes of the research services, namely their institutional structures and their conceptual approach.

- Current staffing levels, operational budgets, the way staff have been trained, and institutional links with other organizations (research, extension, commercial and farmers'), all determine how a research organization functions. They have a major impact on how the ensuing output is disseminated. This report implies the need for change in the way IPM research is undertaken. Fundamental to this need is the way in which staff are trained. In the past, training has mainly been based on a single discipline and has not fostered skills of problem identification and problem solving. Budgets have concentrated on work at research stations. The approach that is being advocated would require funds to enable staff to make frequent farm visits at all stages of the research cycle. It would also require a multi-disciplinary, problem-solving approach. This might not require additional finance, but would certainly involve abandoning some current research initiatives which have little chance of satisfying client (farmer) needs and are essentially single-discipline, or with a research station bias.

- Bringing about change in this situation will require determined effort and a medium-to-long-term commitment. The problem of ensuring that research is addressing the crop protection needs consistent with farmers' priorities is one that can be resolved through multi-disciplinary research in the medium term. The problems of involving farmers in this process are more fundamental; they are faced by almost all agricultural researchers in developing countries (as well as elsewhere), and will require a major shift in the approach to research.

- National policies to promote IPM require close regulation at all stages related to the importation and/or manufacture, distribution, use and disposal of pesticides. In the case of pesticides which do not meet prescribed standards for toxicity, persistence, etc., import and manufacturing bans should be enacted. At a minimum, the conditions laid out by the *FAO Code of Conduct on the Regulation, Distribution and Use of Pesticides* should be adopted.

- Beyond this set of minimal conditions, wider implementation of IPM will be facilitated by an examination of the policies and practices at each stage of the 'pesticide delivery system' to ensure that they are consistent with the policies and practices of the 'IPM delivery system'. Close co-operation and communication between these two 'systems' is essential to create the most conducive environment for farmers' adoption of IPM. Otherwise, there remains the risk, too frequently realized in the recent past, of IPM programmes that are poorly linked with farmers' pest control decisions. Consistent application of IPM within the central pest control strategy to be promoted by national governments must become an important objective of the international donor community in its pursuit of the wider implementation of IPM.

- Price distortions both globally and nationally are a result of vested interests as well as ill-conceived policies. International development agencies need to work more closely with national governments to review the policies that affect pest management. In many instances, the developed countries have policies that are just as contradictory, but they have a better regulatory structure to protect farmers, consumers and the environment in general from the most harmful chemicals.

- The costs to developing countries of *not* bringing their policies in line with the objectives of IPM are relatively greater than the costs to developed countries. This is due both to lack of regulation, leading to increased environmental dangers; and also to higher economic costs involved in both the greater dependence on agriculture, and the potentially greater severity of pest problems, in the developing countries of the tropics. IPM opens new opportunities for farmers to improve traditional agricultural practices, and to complement their other sources of income. The IPM model includes problems as well as advantages, but it cannot evolve without supportive national and international policies that work.

IPM implementation in the developing countries can be substantially accelerated by five major thrusts.

- An improvement in the co-ordination between donor agencies and execution agencies in funding intra- and inter-country projects; this is addressed in *Institutional (Organizational) Mechanisms for Improving IPM Implementation*, p.57, by the proposal for an international IPM council.

- An improvement in the knowledge base available to national programmes, to support changes in government policy and programmes away from unilateral pest control practices, and clearly demonstrating the benefits to be derived from IPM; this is addressed below by recommendations to support global data bases.

- An increase in funding for the development of training materials appropriate to different groups of farmers; this should be done concurrently with 'train-the-trainer' programmes in selected countries.

- An increase in research support for collaborative projects between national programmes and identified IPM expertise (such as in the international agricultural research centres and in advanced institutions), to generate IPM practices appropriate to local farmers and conditions.

- An increase in the level of IPM funding, coupled with a reallocation of present funding, for selected implementation projects in particular cropping systems; these projects should have clear design and evaluation criteria for interdisciplinary pest problem-solving at the field level.

Detailed analyses of each of these have been provided in previous sections of this report, while in the following sections specific activities will be recommended to address the issues.

Improving aspects of IPM implementation

Improving the environment that favours IPM implementation

Almost without exception, most of the technology for IPM has been generated for those ecosystems which require a response to failure of conventional pest control using unilateral approaches. The context in which IPM is to be practised must be improved if there is to be any long-term change in philosophy about pest management. This is particularly important in the Asian context, where a large proportion of farmers and scientists are young people brought up in an era when chemical pesticides were taken as the norm. Part of the philosophical change must include recognition of the complexities associated with managing intensive ecosystems for sustainability. An ability to think in terms of holistic systems is vital to this process, together with appreciation by scientists of farmer responsiveness to new technology. Improvements in the scientific environment must be matched by those in the political/social environment, especially in the role of governments in the lives of rural people. Government policy, implicitly and explicitly, must support IPM implementation. Consumers require education about food produced using low-to-minimal inputs. The specific recommendations are listed below.

- *Increase support to create conducive policy environments.* The case of the FAO Intercountry Rice IPM programme clearly shows the importance of a favourable policy environment for farmers to adopt alternatives to unilateral pest control. The creation of this environment requires scientific proof that clearly spells out the benefits and reduced risks of IPM. Documentation of the evidence would require new efforts depending on the country or ecosystem.

- *Increase the capabilities of national programmes to generate local political support.* Although much has been accomplished by several national programmes and by FAO, only a small proportion of the potential client group has yet been involved. Sensitization of key policy makers, politicians, planners, research managers and extension directors to IPM, and education of researchers, extension workers and technicians in IPM, is urgently needed in a large part of the developing world.

- *Increase the capabilities to conduct problem diagnosis and to evaluate progress with IPM implementation.* Systems analysis as a tool for problem diagnosis is not new and has been demonstrated for IPM in developed-country cropping systems such as potato and apple. The target groups for this activity are researchers, research managers, extension directors and government planners. All three situations favouring IPM—pesticide misuse (pest resurgences); pesticide over-use; and no current pesticide use (*see Pesticide Use in relation to IPM,* p.15)—would lend themselves well to this. National IPM programmes would be the ultimate beneficiaries, with well-conceived research and implementation plans as the output. The plans derived from this process would also clearly show where interdisciplinary co-operation can be optimized, and which is the most direct route to generating a useful IPM 'tool-kit'.

Improving the world-wide system for data collection to evaluate progress with IPM implementation

- *Support the development of national capabilities* in crop and pest monitoring, and in impact assessment. A reliable source of accurate information on the status of crops and pests in farmers' fields is necessary for many IPM activities. In countries which have developed systems for data collection, the benefits have become obvious, both for proactive as well as reactive activities related to IPM. Much expertise exists in the more advanced developing countries on biological and environmental monitoring; this expertise can be tapped to help implement national systems, after suitable modification for local needs.

- *Support the development of a global data base* on crop yield and pest losses. This is required for planning on a global scale, especially in terms of resource allocation between commodities, cropping systems and pests. The global data base used by most planners is still the Cramer data base (Cramer, 1967). There are little reliable data on current levels of losses and because the methodology is substantially distinct from biological monitoring, development of such a data base would require a separate commitment.

Improving the type and rate of technology generation and adoption

- *Develop national programme capabilities* for interdisciplinary IPM research to generate simple IPM decision-making tools. Interdisciplinary research is required to generate the tools for solving practical pest problems in the real world. As with many developed countries, the capability to conduct interdisciplinary IPM research is limited to very few individuals, as the majority of academic institutions are still organized along strictly disciplinary lines. Sufficient methodologies are now available, using systems modelling techniques, to facilitate the conduct of this type of research so that simplified decision aids can be formulated for direct farmer use.

- *Support research on the ecological basis for IPM in agro-ecosystems.* Strategic research aimed at long-term stability of plant-pest ecosystems is lacking in many countries and is urgently needed. This type of research will lead to the design of pragmatic cropping systems that can be implemented with simple technology. Admittedly, this is rather all-encompassing, and includes research on the natural population regulation processes that occur in man-managed ecosystems. This research will require new skills, such as systems analysis and modelling, which are limited or absent in many developing countries. It will also require that many plant protection scientists acquire skills for ecological and epidemiological analyses, and apply them to improve biological, chemical and cultural control, and host-plant resistance.

- *Develop and support national programme capabilities* for on-farm testing and technology extrapolation. On-farm research capabilities are lacking in many national programmes, and because much IPM technology is location-specific, this becomes a vital issue. Technology needs to be verified under farmers' conditions for specific locations and, beyond that, the extent to which technology verified for one site can be applied to other sites needs to be ascertained. All this can be done only if there are capabilities for on-farm research.

- *Support the development of generic IPM training material.* IPM is predominantly knowledge technology, the use of which requires training of the many groups involved. There is currently little training material for most of these groups; much has been improvised from other purposes. If IPM is to become the major approach for pest management in the developing world, this deficiency must be remedied urgently.

- *Support national programme activity in training* of farmers, extension personnel and researchers in IPM. The model used by the FAO Intercountry Rice IPM programme, in which resource persons are recruited for special 'train-the-trainer' activities, is one that could be followed. The same model is used for training farmers and researchers. A systematic programme should be designed, with follow-up activities, to support training programmes in national systems over a finite period.

- *Support the development of an IPM research network* to increase the generation and sharing of appropriate technology. There is need for a mechanism in which international and intra-national exchange of information and sharing of experiences can be facilitated.

Improving the mechanisms to remove constraints to IPM implementation

- *Promote and support prototype IPM action groups in national programmes.* IPM implementation in national programmes could be accelerated by forming within-country action groups, to include representatives from all the parties concerned with the topic. The national IPM committees set up in each of the participating countries of the FAO Intercountry Rice IPM programme in Asia represent a good example which deserves study as a model to extend elsewhere.

Improving the institutional arrangements for IPM

- *Support the development of basic plant protection infrastructure* (institution building) in selected national programmes. IPM cannot be implemented unless there is a basic infrastructure for plant protection in a country. While many countries in Asia have working plant protection systems, the same cannot be said for Africa or Latin America. FAO has been instrumental in developing or strengthening these in many countries and should be encouraged to continue doing so, particularly in a mode amenable to IPM implementation.

- *Support international action to improve co-ordination, monitoring and funding of IPM projects.* Global co-ordination of funding for IPM needs to be improved, with joint priority-setting among the major donors, and milestones for evaluation defined at the outset. Too much has been wasted with too little practical output in the 1970s and 1908s (*see Institutional (Organizational) Mechanisms for Improving IPM Implementation* below).

- *Support the involvement of non-traditional groups in IPM implementation.* The role of non-traditional agencies in IPM should be encouraged, especially the private non-governmental organizations, which currently appear to be more active than government agencies in grassroots extension in several countries.

This section has examined in general opportunities and activities that, if undertaken, would lead to improved IPM implementation in developing countries. In order that this can happen, a new institutional mechanism needs to be developed to facilitate the process; this is discussed below.

Institutional (Organizational) Mechanisms for Improving IPM Implementation

JUSTIFICATION FOR IMPROVING THE INSTITUTIONAL ASPECTS OF IPM IMPLEMENTATION

There is a multiplicity of organizations concerned with IPM at all levels, from field implementation to research, and for national and international policy-making concerned with pesticide use (James, 1990). Large investments have been made by national governments and by international development agencies in the improvement of crop protection, based on IPM concepts.

Yet this report concludes that there have been few successes, especially considering the large outlays of expertise and funds. The reasons for the disappointing results are:

- *Over-emphasis on science-based research* in pest management. Research is, of course, essential, but far too little research has been done that is directly relevant to the practicalities of IPM implementation in the field. The fault for this undue emphasis on research that is impracticable often lies with scientists' conceptions of what is interesting, rather than useful, as well as poor problem definition. Project design is too often based on a 'top-down' approach rather than one which first considers the opportunities and constraints at the level of the farmer and of those directly concerned with helping him/her (*see Constraints on IPM Implementation,* p.45).

- *Inadequate co-ordination of effort* within and between countries, including poor co-operation between national research, training and implementation institutes, and amongst international development agencies.

- *Lack of suitably experienced experts* of high calibre. This has been exacerbated by lack of co-operation between organizations which should seek to use the best experts regardless of nationality or affiliation. There will never be enough experts of the right calibre, but mechanisms are needed to ensure that the best available are obtained.

- *Lack of suitably trained personnel at the national level* responsible for applied research, extension, and farmer training. This is a limitation everywhere in the world, but is particularly crucial in developing countries where such personnel usually suffer from lower status in relation to research workers and administrators.

- *Limitations in training at all levels,* particularly at that of IPM implementation. Much training effort has been expended on university-type education. Some of this is not well conceived in relation to needs; more, and better-planned, training is needed. Training efforts should be better co-ordinated amongst sponsoring organizations in order to ensure that a student receives training suited to his or her needs, and at an appropriate institution.

  The most serious limitation is training at the extension worker and farmer levels, highlighted by the importance placed on this in the FAO South-East Asian rice IPM programme.

- *Lack of a critical mass of resources* over a sufficient period to make a permanent impact on IPM implementation. In this context, it must be expected that implementation will be a relatively slow process. Even where successful procedures have been developed, relatively few farmers have yet benefited from them. Yet most IPM programmes in the past have been funded for a limited duration.

It is easy to criticize past efforts. IPM implementation must be accepted as difficult and complex, involving as it does complicated socio-economic systems, political problems and scientific problems both in the target countries and in the international community. Two general statements may, however, be made.

- There is a need for much closer co-operation amongst the various international development agencies, whose efforts are at present fragmented and sometimes competitive. This applies to work at all levels, from basic/strategic research to applied research and implementation, as well as to training efforts at all levels.

- Implementation of IPM programmes for chosen systems must be much better planned; the projects much better designed than in the past; and relatively long-duration funding assured. Given the magnitude of estimated losses to pests in developing countries of the tropics, the social, economic and environmental costs of excessive use of pesticides, and the large current investments by national governments and bilateral and multilateral development agencies in developing countries, there is merit in considering new institutional mechanisms to increase the efficiency of pest management.

OPTIONS FOR NEW INSTITUTIONAL MECHANISMS

The aim of any new institutional structure should be to improve the efficiency of IPM implementation in developing countries, especially in projects involving collaboration between national programmes and international development agencies. The possible options are discussed in the following sections.

Option 1: Establish a donor consortium to promote implementation of IPM in developing countries

Despite the multiplicity of organizations involved with IPM implementation in developing countries, successes have been very limited. One major reason has been the lack of adequate resources and commitment by donors over a sufficiently long period to make a permanent impact. This situation has resulted in competition for available scarce resources, often leading to fragmented efforts and ineffective collaboration between the development agencies. Consequently the national programmes tend to suffer.

In view of the fact that national programmes are the key elements in the implementation of IPM, any new institutional arrangement must emphasize increased and sustained support to national programmes with much less bureaucracy. The following option is therefore proposed: the establishment of an international consortium of donors to mobilize resources which would be channelled directly to national programmes for IPM implementation. This consortium should comprise members from the international donor community interested in promoting IPM in developing countries.

The proposed terms of reference of this consortium would include:

(i) identification of priority cropping systems needing IPM implementation in national programmes;

(ii) definition of the problems and assessment of the constraints for IPM implementation in national programmes;

(iii) design of appropriate programmes and projects to assist national programmes to overcome these constraints and to implement them successfully;

(iv) mobilization of the resources needed by the national programmes to implement IPM; and

(v) promotion and facilitation of the establishment and operation of sub-regional IPM networks.

In order to achieve the objectives of the terms of reference outlined above, the consortium should utilize existing international development agencies such as FAO which have acquired relevant experience and competence in IPM over a long period in the developing countries. The creation of any additional technical implementing organization or groups would be an undesirable duplication and a waste of scarce resources. The sustainability of IPM programme implementation would be greatly enhanced by the effective participation of national programmes in all stages in the development and implementation of IPM, and by effective collaboration between national programmes confronted with similar pest problems.

Regional IPM working groups/networks are therefore proposed, comprising IPM specialists and practitioners from the national programmes. These networks will increase awareness for IPM, and promote co-ordination of IPM activities, exchange of information and experience at the regional level.

Option 2: Establish a new International Council for Integrated Pest Management

Annual cost: US$ 2.5 million

This option involves the establishment of a new institutional mechanism for enhancing collaboration and efficiency in implementing IPM programmes in developing countries, by founding an International Council for Integrated Pest Management which would meet regularly once or twice a year.

The Council would be a consultative body of approximately 12 members, having the major representation from client countries, and also including authorities in IPM, international agencies involved in IPM such as FAO, and representatives from the donor community, NGOs and the private sector. The International Council would implement its policy through the creation of an IPM resource group which would comprise a Director, Deputy and three senior international IPM officers. Each would be assisted by two post-doctoral fellows as a cost-effective method of increasing the capability of the group. In order to facilitate contacts in the major industrialized countries in support of IPM in the developing countries, the Director could be based in Europe, the Deputy in North America, with the three international officers and their respective two post-doctoral fellows strategically based in Asia, Africa and Latin America.

This option therefore provides for a Council and a Resource Group which has coverage in all three continents of the developing world, as well as Europe and North America. Whereas the Council and the Resource Group require independence to be effective, it is suggested that their efficiencies would be greatly increased by being associated with an organization such as CAB International, which could provide important logistical support through its information services and IPM-related activities, particularly biological control.

The annual cost for this option is estimated at US$ 2.5 million. Its principal functions would be facilitatory in nature, and would include the following activities:

- documenting and learning from past IPM research and field programmes;
- providing an international forum for IPM and promoting IPM internationally as a central strategy within the macro-economic planning and policy formulation of national programmes;
- establishing IPM global priorities and mobilizing resources for implementing IPM programmes;
- facilitating the sharing and exchanging of this information;
- engaging in IPM training (using the above information);
- collaborating with national programmes and international agencies in the design of more effective IPM programmes (this would be achieved by commissioning resource teams to study and develop IPM projects for specific national programmes);
- facilitating the research, development and implementation of IPM in national programmes through technical backstopping, provision of small facilitating grants, and establishing IPM networks; and
- enhancing collaboration in IPM, and promoting its implementation in the developing countries of the tropics.

Option 3: As Option 2, but initially with a Resource Group in Asia only

Annual cost: US$ 750 000

Should resource limitations not allow Option 2 to be considered at this time, some of the same objectives could be achieved by founding an International Council for IPM with a global responsibility, but limiting the Resource Group to a team of three in Asia, where much experience has already been gained and new opportunities exist for further development. The *raison d'être* of this option would be to undertake the IPM activities in Asia on a pilot basis and, if successful, to benefit from the experience gained in Asia before expanding to include similar operations in Latin America and Africa. Having already established a Council with a global responsibility, IPM issues related to Africa and Latin America could be addressed by the Council from the outset, but would not have the advantage of operational IPM teams in those two continents. Acknowledging the need for logistical support, particularly in information services, consideration could be given to locating the Resource Group team for Asia in Malaysia, at the CAB International/IIBC facility; a Malaysia-based team could also work closely with the FAO Intercountry Programme on Rice IPM.

This option, estimated to cost approximately US$ 750 000 per year (less than one third of the cost of Option 2) may be attractive if resources are limited and if preference is given to initiating modest pilot activities in developing countries, within the context of an international council which has global responsibilities for IPM from the outset. The functions and activities for Option 3 would be identical to Option 2.

Option 4: International Consortium on Integrated Pest Management

Annual cost: US$ 1.5-2.0 million

As in Option 2, the Consortium would include representations from client countries and international agencies, as well as donor community members. The primary responsibilities of the consortium and its staff would be to work with national programmes to (i) identify suitable target pests likely to be amenable to control by IPM, and (ii) design suitable programmes or projects based on IPM principles, for submission by the national programmes to international development agencies for support. Some projects might be supported collaboratively by a few agencies.

The fundamental difference from Option 2, where the five key staff are sited individually in five separate continents, is that this option envisages the IPM Action Group as a team of experts working together to help devise and implement successful IPM programmes. The IPM Action Group would comprise a core group of five IPM specialists (including expertise in the social sciences, as well as technical experts). The services of some members of the Action Group could be provided on a secondment basis by interested development agencies. In this way, the agency would benefit from having a staff member (or an expert from one of its specialist agencies) associated with a group concerned with the development of model IPM projects, based on an internationally agreed set of criteria. This mechanism would provide flexibility for agencies to second specialists for appropriate periods. For example, a nominee could take part in a six-month design study of a project of particular interest to the agency, or could be seconded for perhaps five years. Similarly, client countries would be encouraged to second staff to the core group on a short- or long-term basis, so that they could participate fully in the design of projects relevant to their countries, as well as to liaise with their national organizations. Such a group should include the essential range of disciplines needed to design effective programmes and to catalyse integration of efforts by international development agencies.

It is proposed that the Action Group be located close to an institution with substantial capability in IPM, have ready access to information systems, and regular active contacts with client countries on IPM-related matters. In this way, the core group and its visiting associates would benefit from the broader perspectives of the host institution. Such conditions would provide a 'critical mass of experts' and so prove attractive to high-calibre staff of appropriate experience. There are several possible locations which might fulfil these criteria, to varying degrees. They include:

Australia	CSIRO, Canberra/Brisbane
Benin	IITA, Biological Control Unit
France	CIRAD, Montpellier
Kenya	ICIPE, Nairobi
Netherlands	Agricultural University, Wageningen
United Kingdom	CABI/Imperial College, Silwood Park; NRI, Chatham
United States	CICP, University of Maryland

The aim of the Action Group would be to tackle the key problems identified in this report by the Consultant Group, namely, fragmentation of IPM efforts (nationally and internationally); poor problem definition; inadequate design and implementation of many projects which lead to a waste of resources; and need for timely co-ordinated responses to new pest outbreaks.

While it is envisaged that the Group be based at one site, it would spend most of its time in developing countries working with national organizations to design and help implement specific IPM programmes of the kind recommended for action in *Current Status of Pest Management Activities*, p.16.

It is considered essential that the Group work closely with the FAO regional plant protection officers in Asia, Africa and Latin America. Some FAO regional plant protection officers might be seconded to the core group, for short or long periods, to participate in the design of projects of particular interest to FAO. FAO regional headquarters are also envisaged as centres for Consortium activities in tropical continents. Thus members of the Action Group and other seconded staff could be stationed there for appropriate lengths of time. CABI field stations, CGIAR centres and national governmental organizations would be able to provide local facilities for the Action Group, the choice depending on the requirements of the particular IPM project that the International Consortium's IPM Action Group is facilitating.

In conclusion, the emphasis in this option is on facilitating particular field programmes of IPM implementation, rather than adding to the broader aspects of IPM awareness that are already covered by many agencies. The option is envisaged as providing new initiatives in line with FAO policies on IPM implementation.

Option 5: A new and separate institution to implement and execute IPM programmes

This option would involve the establishment of a separate institution, to implement (as opposed to facilitate) and execute more effective IPM programmes at the field level. This option would require significant expenditure to establish and would compete with existing institutions such as FAO and the many bilateral agencies which are already engaged in the implementation of IPM programmes in Africa, Asia and Latin America.

Commentary

No attempt will be made here to assess the relative merits of the five options listed above - a more detailed analysis of the institutional aspects relating to IPM, including both current and proposed organizations, has also been carried out by James (1990). The brief commentary here will be restricted to noting elements common to the five options which were proposed by different individuals and therefore, not surprisingly, have some aspects in common.

Options 2, 3 and 4 are very similar - each calls for the establishment of an international council with broad representation from client countries, and including IPM professionals, FAO, the donor community, non-governmental organizations, and the private sector. In contrast, Option 1 proposes a consortium of members drawn only from the international donor community, with no representation from the client countries and other organizations involved in IPM. Similarly, Options 2, 3 and 4 call for a permanent professional group of IPM experts to assist the national programmes in implementing IPM, whereas Option 1 specifically precludes the creation of any additional technical organization.

Option 4 differs from Option 2 in that the former calls for all the resource staff to operate from one location, whereas the latter calls for separate groups to be permanently based in Asia, Africa and Latin America. Finally, Options 2 and 3 have identical objectives. Option 3 represents a scaled-down version of Option 2, anticipating either resource limitations with Option 2, or an intention to initiate activities with a pilot project to be based in Asia, with later expansion to Africa and Latin America contingent upon success.

Conclusions

Failures in the implementing of IPM in the past can only be rectified by the design of well planned, well focused programmes on specified cropping systems in particular countries. These will provide object lessons for modification and adaptation elsewhere.

The primary task of any new institutional arrangement is to facilitate the preparation and implementation of a selected number of properly designed IPM projects which are acceptable to farmers. There is a critical need to demonstrate, in a range of cropping systems and geographical locations, that IPM works for the farmer, and at the same time justifies the optimism of those who continue to support it, despite the evidence of past failures.

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Appendices

APPENDIX 1 LIST OF ACRONYMS

ABCP	Africa-wide Biological Control Programme (IITA)
ACIAR	Australian Centre for International Agricultural Research
ACRI	American Cocoa Research Institute
AID	Agency for International Development (=USAID)
AIDAB	Australian International Development Assistance Bureau
AVRDC	Asian Vegetable Research and Development Centre
BHC	Benzene hexachloride
BNN	National Bank of Nicaragua
BPH	Brown plant hopper
Bt	*Bacillus thuringiensis*
BYD	Barley yellow dwarf virus
CABI	CAB International
CATIE	Centro Agronomico Tropical de Investigacion y Ensenanza (Costa Rica)
CCCA	Cocoa, Chocolate and Confectionery Alliance (now BCCCA)
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (Colombia)
CICP	Consortium for International Crop Protection
CILSS	Comité Permanent Inter-états de Lutte Contre la Secheresse dans le Sahel (=Permanent Inter-State Committee on Drought Control in the Sahel, ICDCS)
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo (Mexico)
CIP	Centro Internacional de la Papa (Peru)
CIRAD	Centre de Cooperation Internationale en Recherche Agronomique pour le Developpment
CPTS	Crop Protection Technical Services
CSIRO	Commonwealth Scientific and Industrial Research Organization (Australia)
DBM	Diamondback moth
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuaria
FAO	Food and Agriculture Organization

GLH	Green leafhopper, vector of rice tungro virus
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (German Agency for Technical Co-operation)
IARC	International Agricultural Research Centre
ICAR	Indian Council of Agricultural Research
ICIPE	International Centre of Insect Physiology and Ecology (Kenya)
ICRAF	International Council for Research in Agroforestry (Kenya)
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics (India)
IDRC	International Development Research Centre (Canada) (=CRDI)
IFPRI	International Food Policy Research Institute (US)
IIBC	International Institute of Biological Control
IICA	Inter-American Institute for Co-operation on Agriculture
IITA	International Institute of Tropical Agriculture (Nigeria)
INIBAP	International Network for the Improvement of Banana and Plantain
IOBC	International Organization for Biological Control of Noxious Animals and Plants
IPC	Integrated Pest Control
IPM	Integrated Pest Management
IPMAG	Integrated Pest Management Action Group
IRG	IPM Resource Group
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research (Germany)
IUBS	International Union of Biological Sciences
NFTA	Nitrogen-Fixing Tree Association
NGO	Non-Government Organization
NPV	Nuclear polyhedrosis virus
NRI	Natural Resources Institute
ODA	Overseas Development Administration
PADF	Pan-American Development Foundation
PCCMCA	Programa Co-operativo Centroamericano para el Mejoramiento de Cultivas Alimenticos (Mexico)

PESTNET	African Regional Pest Management Research and Development Network
RTV	Rice Tungro Virus
SADCC	Southern African Development Coordination Conference
TAC	Technical Advisory Committee (of the CGIAR)
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
USAID	United States Agency for International Development
WARDA	West African Rice Development Association

APPENDIX 2 LIST OF PARTICIPANTS IN THE STUDY

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APPENDIX 3 PARTICIPANTS AT IPM WORKSHOP, DECEMBER 1989, SINGAPORE

1 Task Force Members

The following were in attendance: Drs George Rothschild (ACIAR), Gabrielle Persley (ACIAR), G. Spendjian (IDRC), Nick Van der Graaf (FAO), John Perfect (NRI) and William Furtick (USAID). Addresses are as shown in Appendix 2.

2 Consultants (Study team)

The following were in attendance: Professors Michael Way and Paul S. Teng, Drs David Groenfeldt and Clive James, and Messrs. Malcolm Iles and John Terry. Addresses are as shown in Appendix 2.

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APPENDIX 4 SAMPLE QUESTIONNAIRE

PEST MANAGEMENT SURVEY: STATUS, IMPLEMENTATION AND OPPORTUNITIES

Form I Survey

MAJOR CROPS (to which this form relates):

NAME, TITLE AND ADDRESS OF RESPONDENT

A BACKGROUND INFORMATION

1 Basic system

1.1 Country/Region covered by Respondent

1.2 What type of farming?

Please tick. (More than one tick may be necessary)

Rainfed ... Irrigated ... Some water control in Senegal, Burkina Faso and Mali sell locally and to produce boards notably rice

'Subsistence' farmers ... rainfed cultivation - sell surpluses locally or to 'produce boards'.

Higher income farmers ... Industrial plantations ...

1.3 Describe crop system:

1.4 Rotation system practised

2 Existing problems and their treatment

2.1 Major pests (e.g. insects, pathogens, weeds and others) or pest-related problems (pests may be a symptom of mismanagement rather than a primary problem). Please highlight key pests and provide any justification for selection of target pests by reference, historical data on losses, consultant reports, other documents.

2.2 Please describe what the target farmers are doing now (if no pest management programme yet undertaken) or were doing before the pest management programme (e.g. government technology package, excessive pesticide use, no pesticide use, traditional practice, etc.). Can you give specific literature citations or attach unpublished results, internal reports, etc?

2.3 What numbers of farmers have adopted new pest management practices and over what area? If available give details, e.g. numbers adopting new pest management practices, rate of adoption and yields.

2.4 Please outline relevant pest management programmes and activities, past or on-going, indicating supporting organizations, national and international and funding agencies.

2.5 What policy changes, if any, have taken place over the past 10 years (e.g. research policy, extension involvement, agricultural prices)?

2.6 Was there evidence before implementation of secondary pest resurgence or development of resistance to pesticides or breakdown of resistant varieties?

B RECENT/CURRENT INITIATIVES IN PEST MANAGEMENT

3 Techniques used

3.1 Please describe monitoring/surveillance practices and warning/forecasting systems used in the pest management programme.

3.2 Are decision thresholds used for various actions? If so please say how they are devised, how they are modified by farmers, what are the decision criteria (pest, location, weather, variety, etc.).

3.3 Please describe briefly the pest management component practices used as listed below:

3.3.1 Improved agronomic practices:
3.3.2 Host plant resistance:
3.3.3 Chemical pesticides:
3.3.4 Mechanical practices:
3.3.5 Biological control methods:
3.3.6 Others (e.g. behavioural):

3.4 Does the pest management system you have described use assessment of risks and benefits in decision making? If so, at the field, farm or national level, and how?

4 Which of the following criteria are used to assess the importance of the pest management programme? Please give references and comments as appropriate

4.1 Environmental/ecological impact:
4.2 Economics:
4.3 Sociological factors:
4.4 Changes in pesticide use:
4.5 Reduce human health hazards:
4.6 Increased yield stability:
4.7 More sustainable production:
4.8 Increased productivity:
4.9 Increased profitability:
4.10 Policy changes:
4.11 Local political support:
4.12 Human skills development:

5 Constraints to pest management

Constraints to a more integrated approach to pest management appear to lie in 4 main areas: 1) generation of knowledge through basic and strategic research; 2) development of pest management through adaptive research; 3) the dissemination of pest management through technology transfer or extension; and 4) the adoption of the technology by the ultimate user - that is, the farmer.

In each of these areas, the constraints can be of 4 different types: a) inadequate institutional structures, resources (staff and facilities) and policies; b) limited informational resources; c) absent or missing technology; and d) poorly understood socio-economic factors.

Please comment on each type of constraint to the implementation of pest management and say how you think the constraint could be removed. Please disregard any items you think are not appropriate or not known.

5.1 Institutional constraints (relate to government policy and to the presence of adequate institutional structures, resources and trained staff)

5.1.1 Basic/strategic research:
5.1.2 Adaptive research:
5.1.3 Extension:
5.1.4 Adoption:

5.2 Informational constraints (relate to the availability and exchange of information within and between different levels)

5.2.1 Basic/strategic research:
5.2.2 Adaptive research:
5.2.3 Extension:
5.2.4 Adoption:

5.3 Technological constraints (relate to the needs for and availability of appropriate technology)

5.3.1 Basic/strategic research:
5.3.2 Adaptive research:
5.3.3 Extension:
5.3.4 Adoption:

5.4 Socio-economic constraints (relate to social, cultural and economic factors affecting the different levels)

5.4.1 Basic/strategic research:
5.4.2 Adaptive research:
5.4.3 Extension:
5.4.4 Adoption:

6 Information on farmers

The extent to which the farmers' situation was established before research began and their participation in planning the pest management programme you have described. (Please comment as appropriate.)

6.1 Farmers' situation

Were the farmers' resources (land, labour, capital and management ability) established at the onset of programme activities?

6.2 Farmer participation

6.2.1 Farmer identified pest problems:
6.2.2 Farmer identified constraints to adoption of pest management practices:
6.2.3 Farmer identified needs:
6.2.4 Farmer evaluation of progress:

C FUTURE PROSPECTS FOR DEVELOPMENT AND IMPLEMENTATION OF IPM PROGRAMMES

7 Your personal views and suggestions

7.1 Please give your opinion on the success of pest management implementation to date.

Successful . . . Partially successful . . .
Disappointing . . . Not successful . . .

7.2 Do you consider that more work is justified at this time? If so, what are the options that should be considered to improve IPM in your area of experience?

7.3 Other comments:

8 Role of various institutions

8.1 We would like your assessment of the appropriate role of various local national institutions for implementing IPM. Please comment as appropriate.

8.1.1 Farmer groups
8.1.2 Non-governmental organizations
8.1.3 Extension services
8.1.4 Government research organizations
8.1.5 Universities
8.1.6 Policy-setting government institutions

8.2 International institutions and organizations

We would also like your assessment of the appropriate role of international institutions and organizations in the implementation of IPM. Please comment as appropriate.

8.2.1 CGIAR research centres
8.2.2 Bilateral (e.g. USAID, GTZ, ODA) and multilateral organizations (e.g. FAO, UNEP, World Bank)
8.2.3 Regional networks
8.2.4 Institutional networks
8.2.5 Agricultural product/service companies
8.2.6 Developed country R&D organizations (e.g. government institutes, universities)

APPENDIX 5 RESPONDENTS TO QUESTIONNAIRES, AND CROPS COVERED

MAIZE groundnuts, cotton, exotic forestry, other crops

Semi-arid tropics, especially Africa and Indian sub-continent

R.H. Cowie
NRI, Central Avenue, Chatham Maritime
Kent ME4 4TB, UK

MAIZE or maize/beans

Nicaragua, Central America

A. van Huis
PO Box 8031, 6700 EH Wageningen
The Netherlands

MAIZE beans, cassava

Latin America

M.A. Vaughan
Regional Plant Protection Officer
FAO/RLAC, Casilla 10095, Santiago, Chile

MILLET	groundnuts, maize Gambia and other Sahelian countries A.G. Carson c/o FAO Representative Banjul, The Gambia
MILLET	groundnuts, maize Senegal and other Sahelian countries V.J. Bhatnagar, C-30, Raghu-Rashmi Bhagwan Dass Road, Jaipur - 302001, India
MILLET	cowpea Niger K. van Elsen c/o FAO, PO Box 2338 Jakarta 10001, Indonesia
MILLET	cowpea, sorghum Sahel D. Laycock Malherbologiste Project Lutte Integree (CILS/FAO) Inran, Maradi, Niger N.D. Jago NRI, Central Avenue, Chatham Maritime Kent ME4 4TB, UK
MILLET	General West Africa S. Sagnia Department de Formation en Protection des Vegetaux Agrhymet Centre BP 12625 Niamey, Niger
MILLET	sorghum, cowpea, rice, maize (minor crops: groundnuts, potato, dolichos beans) Sahel: Cape Verde, Senegal, Gambia, Mauritania, Mali, Burkina Faso, Niger, Chad G.G.M. Schulten Plant Protection Division, FAO Rome, Italy
PASTURES	Costa Rica, Central America J. Hernandez Depto de Entomologia Ministerio de Agricultura y Ganaderia Apartado 10094 Guadalupe, San Jose, Costa Rica

PIGEON PEA/ SORGHUM — cotton

Southern India

A.B.S. King
NRI, Central Avenue, Chatham Maritime
Kent ME4 4TB, UK

POTATOES — onions, carrots

Costa Rica

C.L. Rodriguez
Departmento de Entomologia, Ministerio de
Agricultura y Ganaderia
Apartado 10094, Guadalupe, San Jose, Costa Rica

RICE — Bhutan

M. Bigger
NRI, Central Avenue, Chatham Maritime
Kent ME4 4TB, UK

RICE — soybean, maize, groundnuts

Southern and South-East Asia

K. van Elsen
c/o FAO
PO Box 2338, Jakarta, Indonesia

RICE — Asia

K.L. Heong
IRRI, PO Box 933 Manila
Philippines

RICE — Bangladesh, China, India, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand, Vietnam

P.E. Kenmore
FAO Intercountry Programme for the Development and
Application of Integrated Pest Control in Rice in
Southern and South-East Asia
FAO, PO Box 1864 Manila, Philippines

RICE — mung beans

Asia

J. Rosenberg
NRI, Central Avenue, Chatham Maritime
Kent ME4 4TB, UK

SOYBEAN — wheat

Brazil

F. Moscardi
Embrapa - CNPSO
Caixa Postal 1061, 86001 Londrina, PR, Brazil

WHEAT pastures, rape, sugar beet, corn

Chile

E. Zuniga
S E E Control Biologico, La Cruz,
Inia, Casilla 3, La Cruz, Chile

VEGETABLES especially brassicas

Malaysia: Cameron Highlands, Melaka and Johor

Lim Guan-Soon
MARDI, Serdang
Selangor, Malaysia

VEGETABLES monocultures of tomato, pepper, cabbage

Latin America

M.A. Vaughan
Regional Plant Protection Officer
FAO/RLAC, Casilla 10095
Santiago, Chile

STRIGA in the CILSS IPM Project

Gambia, Senegal, Mali, Burkina Faso, Niger, Chad

P.J. Terry
Long Ashton Research Station
Long Ashton
Bristol BS18 9AF, UK

COTTON Egypt, Pakistan, Peru

D. Campion
NRI, Central Avenue, Chatham Maritime
Kent ME4 4TB, UK

COTTON maize, groundnut, sugar, sorghum, tobacco

Zimbabwe, Malawi

G.A. Matthews
IPARC, Imperial College at Silwood Park
Ascot, Berks SL5 7PY, UK

COTTON Pakistan, Egypt, Peru

M.J. Iles
NRI, Central Avenue, Chatham Maritime
Kent ME4 4TB, UK

COCOA monocrop under jungle or planted shade, cocoa/coconut mixed crop

South-East Asia

R. Day and J. Mumford
Imperial College at Silwood Park
Ascot, Berks SL5 7PY, UK

COCOA sometimes as undercrop with coconuts

Caribbean

E.P. Imle
10802 Bornedale Drive
Adelphi, ML 20783, USA

COCOA monoculture

Central America, Belize, Ecuador

B.H. Waite
AID/S and T/AGR
Washington DC 20523
US

L.H. Purdy
Department of Plant Pathology
University of Florida
Gainsville, FL 32611, USA

COCOA Ecuador

J. Waller
CAB International Mycological Institute (IMI)
Ferry Lane
Kew, Surrey TW9 3AF, UK

COCOA monocrop; sometimes intercropped food crops, oil palm bananas, plaintains

West Africa - Nigeria, Ghana, Sierra Leone

A. Youdeowei
University of Ibadan
PO Box 9761 University Post Office
Ibadan, Nigeria