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Biological control and integrated crop protection: towards environmentally safer agriculture

Proceedings of an international conference
organized by the IOBC/WPRS
Veldhoven, Netherlands, 8 - 13 September 1991

J.C. van Lenteren, A.K. Minks & O.M.B. de Ponti (Editors)

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Preface

R. Cavalloro

President of IOBC/WPRS

The idea for this Conference "Biological Control and Integrated Pest Management: towards an Environmentally Safer Agriculture" was suggested by the "International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palaearctic Regional Section", during the last General Assembly in September 1989 in Florence (I) and we are very pleased to have achieved it. Nowadays, pest management remains a fundamental issue in agriculture and it should not only lead to effective interventions but it should also be conducted with respect for the environment. Agriculture which is sensitive to the requirements and the quality of the environment must direct the necessary treatments, discourage the use of polluting and toxic agents, and stimulate the adoption of alternative technologies: the use of biological and integrated control has for many years been the primary objective of the IOBC. The results achieved so far following the application of these strategies have been very positive.

This Conference was conceived to take an inventory of the situation and to examine together with scientists, industrialists, politicians, extension specialists, producers and consumers the development and the coordination of future actions in integrated agricultural protection and management: the need to progress harmoniously with common rules in order to achieve a healthy and sound agriculture, without harmful side effects, is nowadays a necessity. The commitment and the eminent competence of the participating experts, as well as their expertise in various areas of crop protection, honoured our effort and will lead to further success.

We are sincerely grateful to the Dutch authorities which made this Conference possible. We are also much obliged to the Scientific Committee for defining the main features and the structure of this meeting and to the national and international institutions, in particular to the Commission of the European Communities that supported it. We would like to express our grateful thanks to Prof. J.C. van Lenteren and Dr. O.M.B. de Ponti, chairmen of the Local Organizing Committee, and to Dr. A.K. Minks who efficiently held the secretariat.

Préface

R. Cavalloro

Président de l'OILB/SROP

La réalisation de cette Conférence "Lutte Biologique et Protection Intégrée des Cultures: vers une Agriculture Respectueuse de l'Environnement" a été souhaitée par l'Organisation Internationale de Lutte Biologique et Intégrée contre les Animaux et les Plantes Nuisibles, Section Régionale Ouest Paléarctique, lors de la dernière Assemblée Générale en septembre 1989 à Florence (I) et nous sommes sincèrement heureux de l'avoir accomplie.

La protection phytosanitaire demeure aujourd'hui une pratique agricole fondamentale et elle doit non seulement veiller que les interventions soient efficaces mais encore qu'elles soient exécutées avec le plus grand respect du milieu où l'on opère. Une agriculture attentive aux exigences et à la qualité de l'environnement doit guider les applications nécessaires, décourageant l'emploi des produits nocifs polluants et stimuler l'adoption des technologies alternatives: le recours à des moyens biologiques et à des méthodes de lutte intégrée est depuis plusieurs années l'objectif prioritaire de l' OILB. Le progrès obtenus et les rèsultats déjà atteints grâce à l'application de ces stratégies avancées sont très positifs.

Cette Conférence a été conçue pour faire le point sur l'etat de l'art et examiner ensemble - chercheurs, industriels, politiciens, opérateurs agricoles, producteurs et consommateurs - le développement futur et la coordination des actions en protection et production agricole intégrées: la nécessité de progresser ensemble sur des règles communes pour réaliser une agriculture saine et de qualité, sans effects secondaires néfastes, est aujourd'hui un impératif. L'engagement et la profonde compétence des experts participants, ainsi que leur appartenance à des domaines divers mais rattachés à la protection phytosanitaire, ont gratifié largement notre effort et donnent l'assurance qu'on parviendra à atteindre des résultats importants.

Il a été possible effectuer la Conférence grâce aux autorités hollandaises pour la sensibilité qu'elles ont démontrée: nous leur sommes très obligés. Au Comité Scientifique qui a défini les grandes lignes et la structure de la réunion et aux organisations nationales et internationales qui l'ont appuyée, notamment à la Commission des Communautés Européennes, va également notre reconnaissance. Un profond, vif remerciement au Comité Organisateur Local présidé par M. J.C. van Lenteren et M. O.M.B. de Ponti et dont notre Vice-Président M. A.K. Minks a efficacement assuré le Sécretariat.

Introduction to the Conference

J.C. van Lenteren, A.K. Minks & O.M.B. de Ponti

Organizing Committee

Shortly after the large increase in pesticide use around 1950, biologists started to warn of side effects from applications of these agrochemicals on flora, fauna and the environment as a whole. Entomologists in particular realized that, whilst leading to increased yields, pesticides might also create a variety of agrotechnological problems. A group of leading crop protection specialists in the 1950s was so concerned that they made a plea for the development of integrated pest management (IPM), where different control techniques would be combined, instead of relying solely on chemical control. The Food and Agriculture Organization of the United Nations (FAO) also became very interested and defined IPM as "*Use of all suitable techniques in a compatible manner to reduce pest populations and maintain them at levels below those causing economic injury*".

This early awareness and concern led in the 1950s to the formation of a number of organizations of entomologists and other crop protectionists and agronomists at the global (e.g. FAO and IOBC), European (e.g. IOBC/WPRS and EC) and national levels. This can be regarded as the first phase of IPM, characterized by many activities in the area of fundamental and applied research. However, the actual application of IPM remained very limited. Most farmers and extension workers were not interested: IPM was considered as complicated and time-consuming, and insect and disease control could easily be achieved with pesticides. Consumers were not yet complaining about residues or the environment, and governments encouraged pesticide use in order to obtain higher yields. This was for researchers an often frustrating phase of IPM and it lasted until the end of the 1970s.

Then a number of issues resulted in growing public interest in integrated pest management: pollution through pesticides during their production by the agrochemical industry and application in agriculture became well documented. In particular, ground water pollution created serious concerns, indicating that not only the biological environment of flora and fauna, but also the physical environment was affected beyond acceptable levels. Farmers not only learned that insects and diseases may well become resistant to pesticides, but, moreover, experienced that sometimes new pesticides do not become available in time or that application of pesticides leads to a treadmill of new problems.

These developments resulted in the second IPM phase with the following characteristics:

- farmers themselves asking for alternatives,
- ministries for environment and agriculture wanting to decrease the use of chemical pesticides, and
- consumers demanding products grown with minimum chemical inputs.

These changes in attitude of farmers and policy makers were perceived during the 6th General Assembly of IOBC/WPRS at Florence in 1989. It was thought essential that the IOBC/WPRS, with its long-standing knowledge and experience in IPM, should try to function as a moderator in order to stimulate the implementation of major IPM-regimes.

Until then IOBC/WPRS mainly coordinated research, but now the time had come to disseminate its experience beyond its own circles. The idea for the Veldhoven Conference was thus born. Shortly after the General Assembly, the organizing committee formulated the objectives for the conference including the ways in which it hoped to achieve them:

Objectives:
1. Show where biological and integrated control has successfully been implemented
2. Identify factors limiting further implementation (i.e. in research, policy-making, extension and farmer-use)
3. Develop strategies to increase implementation
4. Present these strategies to the EC and national governments

How to achieve these objectives?
1. Present case studies where there has been successful biological control and integrated control
2. Present a survey of national IPM-oriented crop protection policies
3. Illustrate the crucial role of extension services
4. Develop strategies for further implementation of biological and integrated control
5. Demonstrate commercial biological and integrated control during excursions

The sudden and major demand for IPM in Europe might of course create problems, such as who is providing the know-how for such programmes, and are there commercially applicable programmes for each specific region and crop? During the conference it was clearly shown that although there are several commercially available IPM programmes ready for use, it is far more complicated to develop and implement an IPM programme than to rely on chemical control. Farmers, extension staff and researchers have to be very creative in developing such IPM programmes. Another crucial aspect was that implementation of IPM is only possible where there is active political support by ministries of environment and agriculture.

The Conference contributed significantly to bridging the gaps between all those involved in the further development and implementation of IPM. It created platforms for concerted activities at national and international levels towards greater harmony between agriculture and the environment.

The IOBC/WPRS Conference on Biological Control and Integrated Crop Protection allowed ample time for discussion. This encouraged the participating policy makers, scientists, extension officers and others involved in crop protection and agricultural production to elaborate on further development and implementation of environmentally safer crop protection methods beyond the boundaries of their individual responsibilities. A great deal of time was spent on workshops which resulted in recommendations for relevant authorities at European and national levels (see "Conclusions and Recommendations"). This was the first time that this topic had been discussed in Europe with such a diverse audience, reflecting the growing awareness of an urgent need for significant changes in crop protection.

We would like to thank all colleagues who have assisted us in the preparations of these proceedings: C.J.H. Booij, J. Brodeur, R.A. Daamen, P. van Deventer, J. Hellinga, P. Maas and J. Theunissen, all at Wageningen, The Netherlands; P. Esbjerg, Frederiksberg, Denmark; E. Dickler, Dossenheim, Germany; P.J. Charmillot and J. Freuler, Nyon, Switzerland; J.

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We also gratefully acknowledge the skilful assistance of Mrs. H. van Duin and O.C. Crommelin during the Conference. The latter as well as Mrs. T. de Vries are thanked for the typing of the manuscripts of this book. Special thanks are due to Mr. R. de Rooij for different services in the area of public relations.

Finally, we would like to thank the members of the organizing committee for their excellent cooperation. We have held 25 meetings, and have worked in good harmony with the Executive Committee (which acted as the Conference Scientific Committee) and with the Council of IOBC/WPRS. Last but not least, we would like to thank all our sponsors, who, through their generous contributions, made it possible to hold this conference in such a pleasant setting.

Opening address

J.D. Gabor

State Secretary for Agriculture, Nature Management and Fisheries, The Hague, The Netherlands (presented by P. Ritsema, Director General for Rural Areas and Quality Management, Ministry for Agriculture, Nature Management and Fisheries).

Integrated and biological crop protection in order to realize sustainable, safe and competitive farming is of the utmost importance. Apparently, this is recognized by the organizers and the participants gathered for this conference. Among the participants there are representatives of the member states of the European Communities as well as of Israel, Turkey, Tunisia, Czechoslovakia and Yugoslavia. This attendance indicates the great international interest in the problems of crop protection.

The Netherlands has made quite some progress with the introduction of environmentally safe crop protection. Therefore I am glad to have the opportunity to sketch out the situation here at the opening of this conference.

"Nature can be fought, but never overpowered", a poetic Roman of ancient times once said. It will return with nettles and buttercups, with destructive insects, or with droughts, frosts or gales. Nature has its own laws, which are sometimes in violent conflict with the agricultural interests of man. Farmers have to cope with a partner that is accommodating on the one hand, but which on the other hand has the annoying habit of thwarting their plans time and again. Weeds, diseases and pests have always posed a threat to agricultural production. Man has been searching for ways to arm himself against them and to safeguard the results of his exertions. Throughout the centuries ploughing and weeding, manual removal or scaring off uninvited guests have been part of the daily routine of farmers. Initially, they sought to get the better of nature through cunning plots. Our strategies in the chess game with nature could do with considerable improvement, was the conclusion reached by some seventeenth-century philosophers, on the heels of Francis Bacon and René Descartes. If we are so frustrated by diseases and pests in agricultural crops, we have to bring in heavier weapons, they reasoned.

About two hundred years later it seems even possible to get rid of the more stubborn problems in crop protection. By the middle of this century researchers succeeded in artificially synthesizing agents that could be deployed in the battle against undesirable organisms. At first the results seemed promising. Also because of the application of pesticides, bumper crops were harvested in the post-war Netherlands. For a while it looked as if the 'weapon of chemical successes' was able to defeat weeds, diseases and pests once and for all. After some fifteen years this optimism dampened, however. Rachel Carson's book "Silent Spring", which was published in 1962, revealed the alarming effects of several new pesticides. The author urgently warned for the disastrous consequences that were being overlooked. She meant the increasing resistance of insects and fungi to new agents, and unnatural deaths of fish and birds, as well as the immediate effects on human health of exposure.

Also in The Netherlands restricted groups of people worked on biological and integrated crop protection, before government policy was changed. In the year 1991 we have learned that this is nature's way of warning us against the catastrophic consequences of 'misinterpreted self-interest'. We, the other partner in the concert with nature, are called to order. Everyone concerned with crop protection is urged to seek thoroughly for new, environmentally safe agents and methods. It is clear that crop protection has changed quite a bit over the years. This is closely related to the developments in agriculture and horticulture, resulting in a high degree of intensification which made economic risks increase. Drastic agents and methods were applied to reduce these risks, initially without much consideration for the risks they pose to the environment. The harmful effects on soil, water, air, and flora and fauna were not revealed until much later.

From then on appeals for an effective and quick solution became more insistent. The Netherlands has made good progress in this matter, and not without reason. Particularly Dutch agriculture is characterized by an intensive use of pesticides compared to the surrounding countries. To give you an idea: we use about twenty kilograms of active ingredients per hectare a year. In Belgium, Germany, France and Switzerland the quantities used are considerably lower, that is, 12, 4, 6 and 6 kilograms respectively. Of course these figures are not quite comparable, because we have a more intensive agriculture. It means that Dutch agriculture is facing a difficult and responsible task. In 1989 the Dutch Ministry of Agriculture, Nature Management and Fisheries published the Agricultural Structure Memorandum. This proposes far-reaching changes in order to come to sustainable agriculture. The objective of sustainability is integrated with the more economic and social objectives of agricultural policy. To mention a few: agriculture should maintain its competitive character on both domestic and foreign markets. It should also produce safe foodstuffs under safe working conditions.

As a consequence, a separate policy plan was drafted for the protection of crops: the Multi-Year Crop Protection Plan. The main objective of the plan is to reduce current pesticide use by 30 to 35% in 1995 and by 50% in 2000. A wide range of instruments will be applied to implement the Multi-Year Crop Protection Plan. The Plan focuses on research, extension, education and incentives as well as on legislation. As announced in the programme of this Conference, an official of my Ministry will describe the Plan in detail (see F. Baerselman, this volume).

Sustainable crop protection has to focus on biological and integrated pest control. In several holdings in The Netherlands these crop protection methods have proved to be successful in practice. For example, in glasshouse sweet pepper growing biological pest control of red spider mite and thrips is applied at more than 80% of the total area. In arable farming, integrated control of weeds, diseases and pests is already applied on a limited scale. By a well-considered choice of varieties and crop rotation, by mechanical and thermal weed control, and by choosing pesticides for their range of activity.

Wise crop protection draws heavily on the grower's knowledge and skills. Education and extension are important instruments to keep growers informed of the latest findings and applications. Research and technology provide the information about these findings and applications. Technologically speaking, a lot has been achieved. Biotechnological methods have brought more specific crop protection within reach. Another example is genetic engineering of plants, as a result of which the plants start developing characteristics that make them immune to certain enemies. I wish to stress, however, that the possible risks of growing genetically modified organisms have to be considered carefully.

Developments in computer science should not be left out either. Computerized warning systems contribute to a precise and timely spotting of diseases and pests, thus making it possible to apply specific control measures.

Finally, there are the biological control measures. Besides the existing systems of biological crop protection using predators there are several systems still at the experimental stage, or awaiting approval under the Pesticides Act, which covers agents such as bactericides, fungicides and viricides. Until now the usual approval procedure has concerned chemical pesticides mainly. A separate procedure for biological pesticides has reached an advanced stage of realization.

A change-over to environmentally safe crop protection may also be encouraged by introducing a production mark by way of indication of the quality of the production process. On the one hand, such a mark will inform the increasingly environment-conscious consumers in their choices. On the other, a production mark may improve the competitive character of a product considerably.

We see a great change: until now products of systems with integrated pest control were an exception. In the vegetablessector in a couple of years these products will be the rate and other products will be difficult to sell. Lately, The Netherlands has introduced several production marks for products originating from biological agriculture.

It is evident that there is a lot of movement in the field of Dutch crop protection. The realization of environment-safe crop protection is, as was mentioned earlier, an international matter. Together we are facing the difficult task of achieving this aim. It is the task and the responsibility of extension officers, scientists and policymakers from every country of the world. In my opinion, a conference such as this one, in which all these groups are participating, is therefore of great significance. It is our main task to change our methods of pest control drastically. We are ready for it: we have a good plan and our farmers are willing to change.

The IOBC/WPRS has already worked in this field for years, long before it was recognised in government policy, as it is now. That is why we strongly support this conference. The exchange of information and experience is very important to gain new ideas, develop joint strategies and to harmonize programmes.

I trust that this conference will be a good breeding ground for all this and wish you much luck and fruitful discussions in the week to come.

OILB/SROP: structure, buts et réalisations

R. Cavalloro

Président de l'OILB/SROP
Institut d'Entomologie agricole - Université de Padoue, Italie

Prémisse

La prise de conscience de la sauvegarde de la qualité de l'environnement suite à l'intérêt et à l'attention accrus pour les problèmes sur la santé de notre planète, où les pratiques agricoles de défense phytosanitaire jouent un rôle essentiel, nous amène à nous confronter, à échanger idées et expériences, à identifier ensemble le chemin à poursuivre correctement dans le prochain futur.

Une agriculture renouvelée, attentive aussi aux exigences du milieu devra guider les politiques d'intervention agricole visant à décourager l'emploi de produits nuisibles et à stimuler, par contre, l'adoption de technologies alternatives. Le consentement généralisé vers les pesticides chimiques va disparaître: ils sont aussi impliqués, parmi d'autres produits, dans la grave pollution du sol, de l'eau et de l'air. La lutte chimique traditionnelle a obtenu la faveur incontestée des utilisateurs et a permis de grands succès, avec des bénéfices économiques et sociaux remarquables et immédiats. Ce n'est que de l'apparition des premiers symptômes d'alarme causés par les effets secondaires néfastes et inattendus, dus aux produits de synthèse, que date notre Organisation. L'Organisation Internationale de Lutte Biologique et Intégrée contre les animaux et les plantes nuisibles est donc née comme exigence de défense du milieu.

Constitution et devenir de l'OILB

L'induction de souches de ravageurs résistants aux insecticides accroissant inutilement le nombre de traitements et la recherche d'autres matières actives, l'apparition de nouvelles espèces nuisibles, l'accumulation de produits nocifs dans les cultures, la persistance de résidus toxiques non dégradables dans le milieu, leur accumulation le long des chaînes alimentaires et leur diffusion dans la biosphère, la profonde modification des biocénosis à cause de leur large spectre d'action ayant effet destructif sur la faune utile et les fragiles équilibres naturels, ont profondément sensibilisé les participants au Congrès International d'Entomologie de Stockholm en 1948.

Ils ont adressé une résolution à l'Union Internationale des Sciences Biologiques soulignant l'importance de recherche de nouvelles stratégies et en particulier de la création d'un organisme international pour la lutte biologique. En associant le nouvel organisme à l'UISB, duquel il peut être considéré comme une branche spécialisée, on eut la clairvoyance de lui donner un support immédiat avec une institution prestigieuse de renom mondial. Après un long chemin, en 1955, fut créée la Commission Internationale de Lutte Biologique (CILB), une organisation non gouvernamentale disposant de personnalité morale et composée de membres institutionnels, individuels, bienfaiteurs, honoraires, dont la première réunion officielle eut lieu à Antibes en 1956.

La dénomination "Commission" a été changée en "Organisation" (OILB) lors de l'Assemblée Générale de Montreux en 1965, pour souligner davantage le caractère associatif des participants grâce à l'intérêt manifesté vers la recherche et à l'application de méthodes de lutte alternatives aux produits chimiques. En 1971, à l'Assemblée Générale de Rome, on a décidé de donner une dimension mondiale à cette Organisation, suite à l'attention et à l'engagement accrus des chercheurs et pour concrétiser davantage leurs efforts dans les diverses parties du monde (voir aussi Franz, 1988). Aujourd'hui l'OILB Mondiale est articulée en six Sections Régionales:

SROP = Section Régionale Ouest Paléarctique (Europe, Afrique du Nord, Proche et Moyen Orient)
SREP = Section Régionale Est Paléarctique (Europe de l'Est)
SRAT = Section Régionale d'Afrique Tropicale (Pays au Sud du Sahara)
SRN = Section Régionale Néarctique (Amérique du Nord)
SRNT = Section Régionale Néo Tropicale (Pays d'Amérique Latine)
SRSEA= Section Régionale Sud et Est Asiatique

Organisation et objectifs de la SROP

La structure et le but de l'OILB/SROP sont réglés par un Statut qui vise à l'essentiel, sans alourdir les tâches des responsables, pour un fonctionnement général simple et efficace en même temps. Le Conseil, élu par votation à l'Assemblée Générale, réalise les recommandations qu'il reçoit, définit les programmes d'action et veille sur le bon fonctionnement de la Section.
Un Comité Exécutif, émanant du Conseil et composé du Président, d'un ou plusieurs Vice-Présidents, du Secrétaire Général et du Trésorier, a la responsabilité de la réalisation des programmes et de la gestion générale. Un Comité de Gestion, composé de trois membres élus et choisis au déhors du Conseil, est chargé du contrôle de la gestion financière. Des Commissions, des Groupes de Travail, des Groupes d'Etude, sont responsables de la réalisation du programme.
Les buts que la SROP poursuit et qui sont à la base de son action peuvent être ainsi indiqués:

- promouvoir une protection des plantes valable pour la pratique et respectueuse de l' environnement et assurer la coordination internationale à cette fin
- stimuler les recherches et le développement de méthodes de lutte biologique et de protection intégrée des plantes et sensibiliser l'ensemble des publics intéressés à l'importance économique, écologique et sociale de nouvelles approches de protection des plantes
- organiser la formation du personnel, la publication et diffusion des informations dans le domaine des méthodes de lutte biologique et intégrée.

L'intérêt initial pour la seule lutte biologique s'est bientôt élargi et orienté vers la lutte intégrée, grâce surtout aux chercheurs anglais, et c'est juste ici en Hollande, précisément à Wageningen, que prend naissance en 1959 le premier groupe de travail SROP pour la lutte intégrée en arboriculture fruitière. L'échange d'idées entre experts, l'approfondissement des connaissances, la prise de conscience de l'importance de tous les facteurs de l'agro-écosystème et de la sauvegarde du milieu, ont ensuite amené à mieux définir les lignes d'action de la SROP, sur la base d'un schéma d'évolution des méthodes de protection et de production des cultures, mis au point par des chercheurs allemands, italiens et suisses en 1976 à Ovronnaz. Depuis lors notre Organisation a réalisé une véritable expansion, grâce surtout à la collaboration étroite avec d'importants organismes nationaux et internationaux ayant les mêmes buts, à un fructueux travail d'équipe, à une entente toujours plus forte et amicale et -et ceci est admirable!- à l'effort désintéressé de ses membres. Sans aucun doute l'OILB/SROP est aujourd'hui un point de repère. Les résultats acquis le témoignent: objectifs poursuivis avec succès, applications en plein champ, progrès importants réalisés. Outre les nombreux chercheurs et les membres individuels, on compte aujourd'hui 43 membres institutionnels et 20 membres bienfaiteurs, appartenant à universités, centres de recherche, organisations industrielles, associations agricoles, etc., de 28 différents pays de l'Europe et du bassin méditerranéen.

Activité operationnelle et principaux résultats

Les Commissions, les Groupes de travail et les Groupes d'étude, axés sur la protection d'une culture ou sur des problèmes plus généraux, sont le fondement de l'activité de la SROP.

Commissions

- Publications
- Identification des entomophages
- Action de promotion et de diffusion des activités SROP
- Directives pour un label production intégrée dans la région SROP

Groupes de travail

- Protection intégrée en verger
- Lutte intégrée en viticulture
- Lutte intégrée en agrumiculture
- Lutte intégrée en culture de céréales
- Lutte intégrée en culture de colza
- Lutte intégrée en cultures légumières de plein champ
- Lutte intégrée en cultures protégées: groupe climat continental et groupe climat méditerranéen
- Lutte intégrée contre les ravageurs du sol
- Mouche des fruits d'importance économique
- Utilisation des phéromones et autres médiateurs chimiques en lutte intégrée
- Gestion des systèmes de cultures pour la lutte intégrée
- Pesticides et organismes utiles
- Sélection pour la résistance de la plante-hôte aux insectes et acariens
- Agents pathogènes des insectes et nématodes parasites d'insectes

Groupes d'étude

- Prognose et lutte intégrée contre les noctuelles migrantes
- Lutte intégrée en oléiculture
- Lutte biologique contre les champignons et bactéries phytopathogènes
- Lutte intégrée contre les ravageurs animaux des denrées alimentaires stockées

(NB. see Annexe 1 for English version of this list)

Les résultats obtenus par les Groupes sont importants et les nombreuses publications périodiquement éditées les témoignent. L'application pratique des principes de la protection intégrée est faisable dans plusieurs cas. Les rapports que les experts présentent à cette Conférence le démontrent largement. Parmi les progrès et les réalisations plus considérables sur les principales cultures et à titre d'exemple, on peut souligner:

- de réaliser correctement la défense du vignoble par la protection intégrée;
- en agrumiculture et oléiculture, les programmes de protection intégrée ont été proposés et réalisés avec succès, ayant recours aux agents de lutte biologique, à des méthodologies bio-techniques et génétiques et aux produits chimiques;
- surtout aux problèmes posés par les pucerons, soit pour leurs dégâts directs soit pour leur rôle dans la transmission de graves maladies à virus et l'emploi raisonné de techniques culturales et de pesticides sélectifs semble donner des résultats satisfaisants;

- connaissance plus approfondie de la biologie des phytophages et leur biocénose a permis l'adoption de techniques de prévision des attaques qui ont mené à réduire de 50% le nombre d'interventions de pesticides et la quantité de principe actif;
- protection intégrée, ayant recours préférentiellement à la lutte biologique et à méthodes bio-techniques, ont été mises au point et appliquées en serres à caractère commercial, avec des résultats excellents.

L'action des Commissions de la SROP, constituées pour animer des activités permanentes importantes, a été aussi poussée, à savoir: pour
- publications, à côté d' "Entomophaga", revue de lutte biologique et intégrée, on compte *Bulletins*, traitant particulièrement les activités des Groupes (85 volumes parus dans les dernières 15 année), Brochures, destinées à sujets spécifiques d'ordre technique, "Profile", journal interne d'information, et de nombreux volumes d'actes de diverses activités réalisés directement ou conjointement avec d'importantes organisations internationales, comme résultat de réunions d'experts sur sujets spécifiques, de congrès, de symposia, ou lectures tenues aux cours de formation en lutte biologique et intégrée.
- pour identification des entomophages, service réalisé pour aider les membres à l'identification exacte des espèces utiles et leurs hôtes, on a la collaboration d'une cinquantaine de taxonomistes; ce ne sont pas seulement les chercheurs des pays membres de la SROP qui s'adressent à ce service, mais aussi ceux d'autres continents (p.ex. d'Amérique et d'Australie);
- pour action de promotion et de diffusion des activités SROP, on a intensifié l'étude de moyens pour la valorisation de l'organisation et pour faire utilement connaître les travaux exécutés et les résultats obtenus;
- pour directives pour un label production intégrée dans la région SROP, on vise à la mise au point de directives techniques générales pour l'attribution d'un éventuel label de qualité.

Collaborations

Les experts qui travaillent activement à la réalisation scientifique et technique des programmes sont actuellement un millier et plusieurs activités sont poursuivies en étroite entente avec organismes nationaux et internationaux, gouvernamentaux ou non gouvernamentaux, avec les universités, l'industrie, les cadres techniques agricoles, les producteurs et les consommateurs.

La collaboration internationale avec de grandes organisations est une réalité importante et en progrès: elle est particulièrement soignée et plusieurs actions sont conduites en étroite liaison, par exemple, avec la Food and Agriculture Organization of the United Nations (FAO), l'Organisation Mondiale de la Santé (OMS), l'Organisation Européenne et Méditerranéenne pour la Protection des Plantes (OEPP), et surtout la Commission des Communautés Européennes (CCE). C'est avec les *Directions Générales* de l'Agriculture et de la Recherche de la CCE que sont développés les activités les plus qualifiantes, telles que réunions conjointes d'experts, échange de chercheurs, cours de formation en lutte biologique et intégrée adressés à jeunes chercheurs.

Conclusions

Un long chemin a déjà été parcouru, comme le demontrent les remarquables progrès et réalisations dus à notre Organisation, même si ... on le sait bien ... la recherche n'aura jamais fin! Il est certain que la SROP a développé un travail important et très positif dans le rôle de stimulation à une recherche avancée, de coopération entre chercheurs sur des programmes communs, de diffusion des résultats au fur et à mesure qu'on les obtenait, de formation d'experts, de sensibilisation à l'application de stratégies et de moyens corrects en protection phytosanitaire. Aujourd'hui on assiste à un intérêt accru vers les techniques de protection des plantes inspirées aux principes de l'OILB et ça et là en Europe et ailleurs, plusieurs pays ont déclaré la protection intégrée comme la stratégie officielle à poursuivre. La prise de conscience des dégâts écologiques par l'émission de polluants dans la biosphère a porté la sauvegarde de l'environnement à faire partie même des lois constitutionnelles de certains états comme droit fondamental de la personne humaine et intérêt de la collectivité.

Après une dizaine d'années d'efforts, l'Agence Spatiale Européenne a lancé, il y a un mois et demi, le premier satellite européen (Ers-1) pour le sondage continu et l'étude systématique de la terre, dans le but de pouvoir connaître en temps réel les événements naturels ou provoqués par l'homme, et les données relatives de pollution, pour prendre ainsi immédiatement les initiatives d'intervention selon le problème qui se pose. Des règlements importants sont en train d'être préparés en chaque pays, ainsi que des directives communautaires plus efficaces, soit sur le marché des pesticides que sur la valorisation de productions agricoles qui utilisent des quantités limitées de produits phytosanitaires et d'engrais chimiques. Les firmes industrielles productrices, de même que les firmes commerciales distributrices, se rapprochent davantage aux actions de la SROP et suggèrent officiellement d'améliorer la sécurité d'utilisation de leurs produits en les distribuant suivant les principes du contrôle intégré. Et de plus en plus les politiciens responsables de la politique agricole et environnementale sont convaincus de la validité, de l'actualité et de l'importance des activités et des objectifs indiqués par la SROP.

L'initiative d'organiser cette Conférence, pour faire rencontrer les différentes forces liées à la protection agricole, capables d'arrêter des mesures correctes de gestion de l'environnement et d'essayer de progresser tous ensemble en parfait accord sur des règles communes, a été possible grâce aux Autorités hollandaises auxquelles va notre reconnaissance.

L'emploi correctement discipliné des produits chimiques en agriculture, comme la planification des interventions et la gestion saine des agro-écosystèmes, ne peuvent plus être retardés. Les problématiques qui se posent ont une dimension surnationale et pour y faire face elles nécessitent de réponses globales et de stratégies communes. Il est certain que les indications et l'entente ressortissant de cette Conférence nous aideront à réaliser une agriculture saine et de qualité, mais respectueuse du bien-être de l'homme dans le difficile rapport avec son territoire.

Bibliographie

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Annexe 1

List of Commissions, Working- and Study Groups in IOBC/WPRS

Commissions

- Publications
- Identification of entomophagous species
- Promotion and extension of WPRS activities
- Integrated production: guidelines and certification

Working Groups

- Integrated plant protection in orchards
- Integrated control in viticulture
- Integrated control in citrus fruit crops
- Integrated control in cereals
- Integrated control in oilseed rape
- Integrated control in field vegetables
- Integrated control in protected crops: continental climat group and Mediterranean climate group
- Fruit flies of economic importance
- Use of pheromones and other semiochemicals in integrated control
- Management of farming systems for integrated control
- Pesticides and benneficial organisms
- Breeding for plant host resistance to insects and mites
- Insect pathogens and insect parasitic nematodes

Study Groups

- Prognosis and integrated control of migrant noctuids
- Integrated control in olives
- Biological control of fungal and bacterial plant pathogens
- Integrated control in post-harvest products

Research Section

The state of knowledge in biological and integrated control, and in integrated production

Protection intégrée des vergers européens : situation et évolution

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Résumé

Les fondements, les aspects techniques et la prospective de la protection intégrée des vergers sont examinés. La situation relative à sa mise en oeuvre a été appréhendée au moyen d'une enquête réalisée dans une vingtaine de régions de l'Europe des douze, de l'Autriche et de la Suisse. Une lutte raisonnée, avec des pesticides à moindre incidence écologique, est appliquée sur 6 espèces de rosacées fruitières, sur une surface estimée à 150.000 ha, soit 15% des surfaces des vergers européens de ces espèces. Des réductions de 30% en moyenne du nombre des traitements (10 à 50) par rapport à une lutte chimique conventionelle sont obtenues. Le coût des mesures de surveillance est souvent compensé par les économies réalisées sur les temps de traitement.

De nombreuses méthodes de lutte alternatives à la lutte chimique et non polluantes ont donné de bons resultats expérimentaux, mais bien peu sont déjà appliquées dans une protection intégrée qui ne concernerait que 30.000 ha de vergers. Des actions appropriées sont proposées pour remédier à cette situation, qui a pour conséquence que sur près de 1,8 million d'hectares de vergers européens, la lutte chimique intensive continue alors que l'on a la possibilité technique d'agir autrement.

Introduction

Dès l'origine de l'Organisation Internationale de Lutte Biologique (OILB) un groupe de travail, "Lutte intégrée en vergers" s'est constitué. Il a commencé à préparer les bases méthodologiques permettant l'estimation des risques par rapport à des seuils de tolérance économique et l'aménagement de la lutte chimique contre les ravageurs. La gestion écologique de la protection phytosanitaire était déjà une des préoccupations importantes, se traduisant notamment par l'étude de la sélectivité des pesticides vis-à-vis de l'entomofaune utile, qualifiée d'auxiliaire.

Des expériences de lutte (chimique) raisonnée étaient engagées dès les années 1970 dans les vergers commerciaux de la plupart des pays européens, au moment où l'OILB se subdivisait en sections régionales dont la SROP (Section Régionale Ouest Paléarctique). La prise en considération de l'ensemble des ennemis des vergers (ravageurs animaux, maladies parasitaires, mauvaises herbes) dans une lutte plus cohérente, comportant à la fois des procédés alternatifs à la lutte chimique et un élargissement des interventions à d'autres facteurs spécifiques au verger et à son environnement, s'est ensuite imposée et a été désignée sous le terme de Protection intégrée (OILB/SROP, 1977).

Parallèlement à cette évolution, les applications pratiques en verger ont constamment progressé, surtout depuis une dizaine d'années, grâce à trois types d'actions associant dans un cadre le plus souvent régional des partenaires des services publics, des instituts techniques, de la profession agricole, selon des structures et des modalités très diversifiées. Ce sont:

1. La recherche et l'expérimentation permettant d'acquérir les références techniques sur la protection intégrée des vergers de Rosacées fruitières et d'améliorer les modalités

d'application, en relation notamment avec les progrès enregistrés dans les domaines de la prévision des risques et des moyens de lutte plus spécifiques.

2. La formation spécialisée des arboriculteurs et de leurs conseillers par des stages d'initiation pratique et de perfectionnement.
3. L'information technique sous différentes formes: édition de brochures, notamment par l'OILB/SROP, de guides, de notes, réseaux de liaison téléphonique et plus récemment télématique mis en place par les Services d'Avertissements ou par des organisations spécifiques aux actions de protection intégrée. Un appui technique aux agents chargés du développement agricole complète souvent ces sources d'information.

Après avoir rapidement rappelé les bases de la Protection intégrée des vergers, nous présenterons la situation actuelle au niveau de son application pratique des points de vue technique, statistique et socio-économique, puis nous analyserons des éléments de prospective, découlant des progrès en matière de recherche.

Tableau 1. Evolution des systèmes de protection phytosanitaire des vergers (adapté de Milaire dans Audemard et al., 1986; Milaire, 1991)

1. LUTTE CHIMIQUE INTENSIVE (=LUTTE CHIMIQUE AVEUGLE)
Interventions empiriques ou systematiques effectuées selon une périodicité préétablie (calendrier de traitement).
2. LUTTE CHIMIQUE BASEE SUR AVERTISSEMENTS PHYTOSANITAIRES
Interventions adaptées au risque moyen d'infestation des organismes nuisibles apprécié **au niveau de la petite région agricole** par un Service d'Avertissements phytosanitaires (public ou privé) qui diffuse des mises en alerte et des avis circonstanciés de traitements.
3. LUTTE (CHIMIQUE) RAISONEE*
Interventions décidées après estimation du **risque réel** apprécié à l'échelle de la parcelle par la mise en oeuvre de **méthodes appropriées** d'observation et de surveillance des niveaux de population des ennemis des vergers, ainsi que de la présence et de l'activité des organismes auxiliaires et par référence à des **seuils de tolérance**, en faisant appel à des **pesticides** choisis selon des critères de **moindre incidence écologique.**
4. PROTECTION INTEGREE**
Interventions décidées selon le processus et les critères définis pour la lutte raisonnée mais faisant appel à **plusieurs procédés de lutte judicieusement associés** (moyens biologiques, biotechniques, agrotechniques, chimiques...) et en prenant en compte les **facteurs biotiques participant à la limitation naturelle** des ennemis des vergers: résistance ou tolérance variétale, mesures phytotechniques (mode de conduite, nutrition...), environnement végétal (envisagé comme réserve d'une entomofaune utile).

* Termes équivalents dans d'autres langues: Lutte dirigée (CH), Lotta guidata (I), Supervised control (GB), Gezielte Bekämpfung (D), Lucha razonada (SP), Luta dirigida (P)

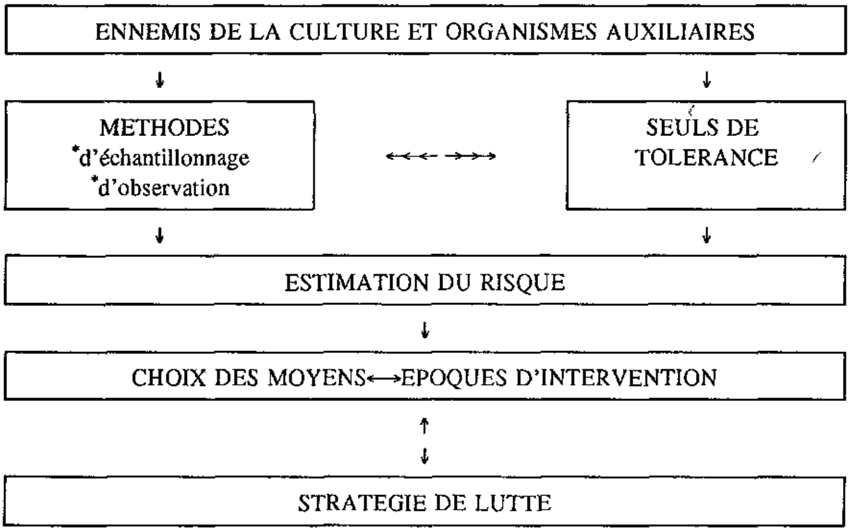
** Termes équivalents dans d'autres langues: Protezione integrata = Protezione ecologica (I), Integrated crop protection = Integrated fruit protection (GB), Integrated pest management (EU), Integrierter Pflanzenschutz (D), Control integrado (SP), Proteccao integrada (P).

Les fondements de la protection intégrée des vergers

On se réfère bien évidemment aux principes de base de la protection intégrée des cultures, laquelle vise à gérer écologiquement et économiquement les interactions dans les agroécosystèmes. On considère la notion de risque de dommages par les ennemis des vergers, par référence à des seuils de tolérance économique et celle d'aménagement de la lutte, en tenant compte de l'action des facteurs naturels de limitation et en intervenant si nécessaire de la façon la plus spécifique possible vis-à-vis des organismes nuisibles.

Les systèmes de protection phytosanitaire des vergers sont essentiellement évolutifs (Tableau 1). Selon la manière de décider des interventions (prévision des risques) et selon le choix des moyens d'intervention, on distingue des phases d'intégration des progrès scientifiques et techniques différentes: lutte chimique basée sur des avertissements phytosanitaires, lutte raisonnée, protection intégrée, qu'il est indispensable de définir (Tableau 1).

Figure 1. Présentation schématique de la démarche suivie (d'après Milaire, 1990)



La démarche concrète suivie en verger, qui concerne aussi bien la lutte raisonnée que la protection intégrée, et **appliquée à l'échelle de la parcelle** consiste à (Figure 1):

- Surveiller les ennemis du verger, particulièrement ceux qui sont toujours dangereux dans la situation considérée (qualifiés d'ennemis-clés) par des méthodes d'observation appropriées et codifiées. Il s'agit d'estimer les populations des ravageurs, la menace des maladies parasitaires, et des antagonistes.
- Evaluer le risque de dommages par référence à des seuils de tolérance, assimilés le plus souvent à des seuils d'intervention, en tenant compte de l'action probable des auxiliaires entomophages.
- Décider de l'opportunité d'une intervention et de ses modalités, dans des stratégies de lutte se référant aux moyens disponibles et aux époques d'application. Ceci afin de maintenir les ennemis à un niveau tolérable et non de les éliminer. Dans le cas de la lutte chimique, on tient compte pour le choix des pesticides des critères d'efficacité sur la ou les espèces cibles à combattre simultanément et des critères de moindre incidence écologique. Cette dernière est caractérisée par un faible niveau de toxicité du pesticide pour l'homme, les vertébrés et les

animaux utiles, un champ d'activité réduit, une bonne sélectivité vis-à-vis des arthropodes utiles incluant les pollinisateurs, la faible pollution du milieu environnant, des effets secondaires indésirables aussi réduits que possibles.

Situation de la protection intégrée dans les vergers de rosacées fruitières européens

Les aspects techniques de la mise en oeuvre de la protection intégrée ont été examinés à partir des publications scientifiques et techniques relatives à ce sujet, dont une sélection est donnée dans la bibliographie, incluant dans la mesure du possible les documents régionaux. La situation relative aux données quantitatives et socio-économiques a été appréhendée au moyen d'une enquête que nous avons réalisée au printemps 1991 auprès des collègues les mieux placés pour nous communiquer les informations sur la protection phytosanitaire des vergers de leurs pays ou régions (Tableau 2), ainsi que d'après une étude du CEMAGREF (Fady & Morin, 1986) en ce qui concerne les motivations des arboriculteurs pratiquant une lutte raisonnée.

Aspects techniques

On peut dire d'une manière générale que l'on dispose des outils permettant d'appliquer en verger de pommiers, poiriers, pêchers et nectariniers, abricotiers, pruniers et dans une moindre mesure cerisiers, ce que nous avons défini précédemment comme une lutte raisonnée (Tableau 1). Ce sont:

- Les méthodologies d'observation et de surveillance des ennemis des vergers et des organismes auxiliaires entomophages (contrôle visuel, piègeages, battage et frappage, modèles de simulation de l'évolution sur ordinateur, appareils de prévision des risques pour la Tavelure du pommier...), dont les modalités d'applications décrites dans les guides et brochures varient plus ou moins selon les pays et les régions.
- Les seuils de tolérance et d'intervention se référant à ces méthodes et adaptés à chaque espèce fruitière concernée pour une région donnée ainsi qu'aux stratégies de lutte et aux considérations économiques.
- Les listes de pesticides préconisés selon les critères d'efficacité et de moindre incidence écologique. Elles comportent souvent un classement en: produits recommandés, utilisables dans certaines conditions, complétés dans les cahiers des charges de production fruitière intégrée par les produits interdits. Ces listes sont aussi établies en fonction :
  a) de l'importance relative des organismes nuisibles;
  b) de la disponibilité des pesticides dans la région résultant de la législation ou de la politique commerciale des Sociétés de produits phytosanitaires;
  c) des exigences des acheteurs de fruits. Il en résulte, d'une part que les préconisations présentent des différences entre régions, d'autre part que certaines stratégies de lutte sélectives sont souvent inapplicables par suite de l'indisponibilité des moyens, ainsi que l'a montré une enquête de L. Blommers (Communication personnelle). Il faudrait donc prévoir des mesures appropriées pour remédier à cette situation.

L'application de la lutte raisonnée dans les vergers de l'Europe de l'Ouest s'est traduite par: une diminution du nombre des traitements (Tableau 2), le recours prioritaire à des pesticides à moindre incidence écologique, l'enrichissement de la faune auxiliaire plus marquée lorsque l'environnement végétal des vergers constituait des réservoirs (haie brise-vent, bosquet...). Nous donnerons deux exemples montrant l'action bénéfique de cette faune auxiliaire:

1. Le rôle capital de la punaise prédatrice *Anthocoris nemoralis* F. dans la régulation des populations du Psylle du poirier *Psylla pyri* L.. Sa préservation par la lutte raisonnée a permis de diminuer des 2/3 le nombre de traitements visant le Psylle, (Atger & Bassino, 1984).

2. La suppression quasi totale des traitements contre l'Acarien rouge *Panonychus ulmi* Koch dans les vergers de pommiers où sont réapparus des acariens prédateurs Typhlodromes, notamment les souches résistantes aux insecticides organophosphorés. Cependant cette situation a parfois engendré un effet malencontreux dans la mesure où l'arboriculteur ne s'est préoccupé dans le choix des pesticides que de la sauvegarde des Typhlodromes, négligeant celle du reste de la faune utile.

Comme nous le verrons plus en détail ultérieurement l'intégration de nouveaux moyens de lutte, qualifiés d'alternatifs à la lutte chimique commence à intervenir. On peu citer:

- la lutte par confusion sexuelle des mâles contre la Tordeuse orientale du pêcher *Cydia molesta* Busck qui concerne déja 7 000 ha environ de vergers en Espagne, France et Italie,
- la lutte biologique contre l'Acarien rouge en verger de pommiers par lâchers inoculatifs de Typhlodromes à partir de vergers-réservoirs (Baillod et al., 1989; Blommers, 1989) qui couvre une superficie de plusieurs milliers d'hectares en Europe.

Les arboriculteurs seront d'autant plus aptes à utiliser avec profit ces innovations, dans le cadre d'une protection intégrée de leurs vergers, qu'ils auront déja réalisé la phase de lutte raisonnée.

Les bilans annuels des opérations de lutte raisonnée et de protection intégrée offrent une opportunité pour préparer l'inévitable évolution des systèmes : apparition de problèmes nouveaux (introduction d'ennemis, résurgence de ravageurs secondaires), difficultés dans la maîtrise de certains ennemis, gestion de la résistance aux pesticides, efficacité de nouveaux pesticides et procédés de lutte... C'est là qu'apparait la nécessité d'une *organisation minimum de soutien* et de dialogue entre les différents acteurs de la protection intégrée, afin d'assurer les échanges d'information et la rétroaction indispensables au bon fonctionnement des systèmes.

Données quantitatives (surfaces et exploitations)

Nous avons réalisé une enquête sur la protection intégrée des vergers (oliviers et citrus exclus) dans une vingtaine de pays ou régions productrices de fruits de l'Europe des douze, de l'Autriche et de la Suisse. Les résultats montrent que 6 espèces de rosacées fruitières sont concernées par ce que nous avons défini comme une lutte raisonnée, dont l'importance a été estimée et non recensée (Tableau 2). Il s'agit des: pomme, poire, pêche et nectarine et dans une moindre mesure, prune, cerise, abricot. Il faut cependant souligner que ce qui est déclaré comme étant une lutte raisonnée n'est probablement dans certains cas qu'une lutte selon des avertissements phytosanitaires améliorés. C'est-à-dire qu'à partir de parcelles pilotes, suivies avec précision, on effectue une prévision des risques qui est extrapolée à l'ensemble des vergers d'une commune ou d'une petite région agricole. Il convient de rappeler que le raisonnement doit impérativement intervenir à partir des données collectées dans le verger où il sera appliqué.

Les vergers bénéficiant d'une lutte raisonnée dans les régions où elle est réalisée représentent une superficie totale de 145 907 ha, soit 33,7 % de l'ensemble des superficies des espèces fruitières correspondantes. Si on utilise ce pourcentage comme base d'estimation pour les vergers des quelques petites régions n'ayant pas répondu à l'enquête on pourrait avancer le chiffre de 150 000 ha dans les pays de l'Europe des douze plus l'Autriche et la Suisse. Ce qui, rapporté aux 1 000 000 d'hectares de vergers des 6 espèces précitées (données 1986 selon EUROSTAT (1989) + surfaces Autriche et Suisse 1990), ne représente plus que 15 % environ. Dans cette situation on relève donc de larges possibilités d'extension que nous argumenterons de la manière suivante : a) plusieurs pays et régions ne se sont pas encore engagés dans cette voie, b) dans les régions d'application, la majorité des surfaces de vergers ne sont en général pas encore concernées car le pommier est l'espèce qui bénéficie le plus d'une lutte raisonnée et la prise en compte des autres espèces fait baisser fortement la moyenne. C'est ainsi qu'en Rhénanie-Palatinat on passe de 35 %

Tableau 2. Application de la lutte raisonnée en verger de rosacées fruitières de l'Europe des douze, l'Autriche et la Suisse

Pays/Régions	**Espèces Fruitières concernées par ordre d'importance**	**Superficie totale de ces espèces en ha**	**Superficie en lutte raisonnée(1)**		**Exploitation en lutte raisonnée**		**% Economie du nombre de produits de traitement**	**Source d'information**
			ha.	**%**	**Nombre**	**%**		
AUTRICHE	Pommier, Poirier	8590	4165	48,5	1284			F Polesny, E Höbaus
ALLEMAGNE (ouest)								
-Rhéanie, Bad Wurtemberg, Niederele, Schleswig-Holstein	Pommier	23 200	5 360	23,1	1 224		-25,prod. intégrée- -15	Galli et Sessler(1991)
-Rhéanie-Palatinat	Pommier, Cerisier, Prunier, Poirier	6 700	1 020	15,2	250		-30	E Jörg
ANGLETERRE	Pommier, Poirier	23 805	16 660	70	415		- 25 à - 30	J Cross, J Turnbull ('90) Cross/Berrie('90)
BELGIQUE								
-Flandres	Pommier, Poirier	15 000	9 000	60	160	10	- 20	C de Schaetzen
-Wallonie	Pommier, Poirier	1 500	400	26,6	40		- 30 à -40	R Marcelle
ESPAGNE								
-Aragon	Pêcher, Pommier, Poirier	29 087	6 451	22,2	3 296 (16 ATRIAS)		- 30 à -30	R Balduque
-Catalonie (Lérida)	Pommier, Poirier, Pêcher	29 315	14 325	48,9	3 530 (42 ATRIAS)		- 31 à -44	I Franco
-Murcia	Pêcher, Abricotier Pommier, Prunier	29 585	687	2,3	2 078			A Lacasa
-Alicante, Castellon et Valencia			0 pas de	lutte	raisonnée			A Garrido
FRANCE								
-Sud-est (Rhône-Alpes, Provence, Languedoc)	Pommier, Poirier, Pêcher(table, con-serve), Cerisier, Abricotier	55 800	9 700	17,4	1 338	2à10	-20 à -50	M Blanc, G Champetier, M Fabregues, JP Gendrier, JP Geraud, B Sauphanor
-Sud-ouest (Aquitaine Limousin, Midi-Pyrénées -Rousillon)	Pommier, Poirier	16 915	2 375	14	380		-10 à -30	R Bourgouin, C Perrau, P Speich
	Pêcher, Prunier d'Ente	12 000	30	0,3				D Carlo
	Pêcher, Abricotier, Cerisier	11 200	1 420	12,7	120		-38	J Nicolas
-Alsace, Ile de France Centre, Pays de la Loire	Pommier, Poirier	17 900	10 617	59,3	1 384	15à90	-0 à -20	C Gachon, J Richier de Forges J Robin, JP Thermoz, M Trillot

Tableau 2 (suite). Application de la lutte raisonnée en verger de rosacées fruitières de l'Europe des douze, l'Autriche et la Suisse

Pays / Régions	Espèces fruitières concernées par ordre d'importance	Superficie totale de ces espèces en ha	Superficie en lutte raisonnée (1)		Exploitation en lutte raisonnée		% Economie du nombre de produits de traitement	Source d'information
			ha.	%	Nombre	%		
GRECE			0 pas de	lutte	raisonnée			C Souliotis
ITALIE								
-Aoste	Pommier,Poirier	430	20	4,6			-0 à -50	C Duverney
-Emilie romagne	Pommier,Poirier, Pêcher,Abricotier Prunier,Cerisier	76 000	14 750	19.4	450		-25 à -30	M Ceci
-Haut Adige	Pommier,Poirier	16 800	13 000	77.4	5 902		-50 (tonnage	H Oberhofer
-Trentin	Pommier(Poirier)	13 000	10 400	80	7 000		de	M Pontalti
-Piemont Sondrio/ Valteline)	Pommier	1 100	900	81,8	1 000		pesticide) -20 -30	A Baiocchi
PAYS BAS	Pommier,Poirier	22 242	22 242	100(3)	1 250		/	L Blommers EJM Regouin
PORTUGAL							-23 à -63	
-Ribatejo et Oeste	Pommier,Poirier	16 400	205	1,3	122		insecticide	C Matias
SUISSE	Pommier,Poirier, Cerisier,Prunier	6 540	2 180	33,3	1 100		-20	A Stäubli Th Wildbolz
TOTAL		433 109	145 907	33,7	33 323			

(1) Incluant le vergers bénéficiant d'une protection intégrée

(2) ATRIAS = Agrupacion Tratamientos Integrados en Agricultura (Groupements pour les traitements intégrés en agriculture)

(3) Les vergers bénéficiant d'une protection intégrée représentant 25 % de la supercie totale

des surfaces de pommiers conduites en lutte raisonnée à 15,2 % (E. Jörg, communication personnelle). Pour les fruits destinés à l'industrie (cidre, conserve) et le prunier d'Ente la lutte raisonnée commence seulement à se développer, c) le nombre d'exploitations conduisant une lutte raisonnée est souvent relativement important par rapport à la superficie bénéficiant de cette lutte. La moyenne générale est de 4,4 ha par exploitation, mais selon les régions et les pays on va de 0,3 à 56,3 ha, d) les organisations spécifiques aux actions de protection intégrée ont des plans de développement ambitieux.

Pour le moment, faute de méthodes de lutte alternatives à la lutte chimique suffisamment disponibles, la protection intégrée n'est effectivement mise en oeuvre que sur des superficies limitées, que l'on peut estimer à 30 000 ha sur la base de la lutte par confusion sexuelle, des lâchers de Typhlodromes et de la lutte microbiologique. La surface des vergers de rosacées fruitières dans les pays d'Europe précités était de l'ordre de 1 758 000 ha (données 1986 selon EUROSTAT (1989) + Autriche et Suisse), chiffre incluant 780 000 ha d'amandiers conduits pour les 2/3 en culture extensive peu ou pas traitée. On peut souligner à ce sujet que l'on a l'habitude de parler des cultures fruitières en terme de tonnages de fruits produits, alors qu'en matière d'environnement ce sont les surfaces des vergers qui sont à considèrer. Il y aura donc lieu de prendre garde aux effets possibles de l'intensification de la culture de l'amandier. Si on ajoute les vergers de toutes les espèces fruitières, à l'exclusion des oliviers et citrus, on a un total de 2 450 000 ha environ (sources précitées). La lutte raisonnée ne couvrirait plus alors que 6,1% des surfaces de vergers. D'une autre manière on peut estimer que la lutte chimique intensive et ses inconvénients sur l'environnement affecte toujours près de 1 800 000 ha de vergers de l'Europe des douze, l'Autriche et la Suisse. Les 2/3 des amandiers conduits en culture extensive n'étant pas pris en compte. Cela montre le chemin qu'il reste à parcourir pour vulgariser les techniques permettant de changer les pratiques dans ce domaine. L'action doit évidemment englober les espèces fruitières pour lesquelles les modalités de lutte raisonnée ne sont pas encore au point.

Aspects socio-économiques.

Les informations émanant de la plupart des régions font ressortir que la lutte raisonnée entraine des réductions de l'ordre de 30% en moyenne dans les nombres de traitements appliqués en verger par rapport à une lutte chimique conventionnelle (Tableau 2). Le terme traitement correspond ici à produit phytosanitaire, on peut donc avoir plusieurs produits appliqués lors du même passage de l'appareil de traitement. Cette réduction des traitements apporte une économie sensible qui se traduit presqu'essentiellement au niveau de l'achat de produits phytosanitaires. On observe de grandes variations dans les chiffres selon les régions, les espèces fruitières et les vergers d'une région (Tableau 2). La diminution des traitements, analysée par famille de produits, va de 40% à 70% pour les insecticides, 50 à 100% pour les acaricides et seulement 0 à 30, voire 40% pour les fongicides. Cela montre tout ce que l'on peut attendre des progrès en matière de lutte contre les maladies parasitaires et notamment de la sélection et de l'utilisation de matériel végétal résistant. Il faut cependant souligner que les pesticides sélectifs et plus encore les moyens spécifiques de lutte sont en général plus coûteux que les pesticides à large champ d'activité et que cela réduit donc l'économie réalisée par la diminution du nombre de traitements. Le temps de travail consacré à la surveillance des vergers estimé par J.P. Gendrier (communication personnelle) à 8% du coût des produits phytosanitaires, est à peu près compensé par le temps récupéré par la suppression de passages de l'appareil de traitement. Il est évident que la dimension des vergers et la structure parcellaire de l'exploitation influent nettement sur ce coût.

Mais on ne saurait ignorer les données qualitatives, même si par définition elles sont difficiles à chiffrer. Il s'agit de : la moindre pollution de l'environnement résultant de la diminution du nombre de traitements et de leur volume (Croaa & Berrie, 1990) ainsi que du choix de produits sélectifs, la préservation de la faune auxiliaire incluant les pollinisateurs, la diminution des risques dus à la manipulation des pesticides par l'arboriculteur, la suppression ou la diminution des résidus de produits toxiques sur les fruits récoltés. Dans cette optique il est évident que la protection intégrée, qui privilégie les méthodes de lutte alternatives à la lutte chimique et la restauration d'une régularisation naturelle des populations d'ennemis des vergers, va bien plus loin que la lutte raisonnée et représente la voie d'avenir en la matière.

Il est particulièrement utile de s'intéresser aux motivations des arboriculteurs qui pratiquent une lutte raisonnée, car on peut ainsi cerner les facteurs qui bloquent ou freinent son développement. D'après une enquête effectuée en France (Fady & Morin, 1986) ces motivations sont de 3 sortes:

- la diminution du coût des mesures de protection, principalement celles visant les acariens phytophages,
- des considérations d'ordre écologique comme : la protection de la faune utile et de l'environnement, la diminution des résidus sur les fruits traités, la protection de la santé de l'utilisateur,

Tableau 3. Moyens de lutte alternatifs à la lutte chimique contre les arthropodes ravageurs de vergers de rosacées fruitières européens

ESPECE OU GROUPE D'ESPECES NUISIBLES (1)	LUTTE BIOLOGIQUE PAR ENTOMOPHAGE (2)	LUTTE MICROBIOLOGIQUE (2)	MOYEN BIOTECHNIQUE (2)	MOYEN GENETIQUE (SELECTION) (2)
LEPIDOPTERES				
■ Carpocapse	☼	☼☼☼ CH,D	☼☼☼ A,CH	☼
Tordeuses monovoltines		☼☼		
■ Tordeuses de la pelure				
Capua		☼☼☼ CH,NL	☼☼	☼
Pandemis, Eulia, A.podana		☼	☼☼	☼
Noctuelles Gothica		☼☼		
Cheimatobie		☼☼☼ CH,D,F,I,NL		
■ Zeuzère	☼	☼☼	☼	
Cossus			☼☼☼ F,I	
Sésie			☼☼	
■ Tordeuse orientale du pêcher	☼		☼☼☼ E,F,I	☼
Petite mineuse du pêcher			☼☼	
■ Carpocapse des prunes			☼☼	
HOMOPTERES				
■ Psylle du poirier	☼☼			
■ Aphidés Puceron cendré	☼			☼☼☼ I,F
Puceron lanigère	☼☼☼ CH,F			☼☼☼ F,GB,NL
■ Puceron vert du pêcher	☼		☼	☼☼
Coccinés Pou de San José	☼☼☼ CH,D,E,F			
Coccinelle du mûrier	☼☼			
DIPTERES				
■ Mouche méditerr. des fruits			☼☼	
■ Mouche de la cerise			☼☼	
ACARIEN ROUGE	☼☼☼ CH,E,F,GB			☼
NEMATODES	I,NL			☼☼

(1) ■ Ennemi-clé

(2) Moyens de lutte:
☼: Stade de la recherche; ☼☼: Expérimentation positive; ☼☼☼: Dejà appliquée (pays);

- la maîtrise du processus de protection phytosanitaire du verger et de la récolte, évitant ainsi les impasses techniques telles que : apparition de souches résistantes (Puceron vert du pêcher *Myzus persicae* Sulz., Acarien rouge, Tavelure *Venturia inaequalis* (Cke) Wint., Psylle du poirier) et d'ennemis secondaires, ainsi que les pertes de récolte par échec de la lutte.

Il est curieux de constater que souvent la première approche privilégie le choix de la méthode de lutte alors que, plus celle-ci est "pointue" plus elle exige une parfaite intégration et le suivi de la démarche présentée dans la figure 1. Depuis cette enquête deux éléments ont pris une place prépondérante dans les motivations: a) la diminution des résidus sur les fruits récoltés à cause, des implications possibles sur leur commercialisation dans le cadre international, b) le souci de valoriser ou de mieux vendre la récolte. Cela conduit l'arboriculteur vers une conception plus globale du raisonnement, qui est étendu à l'ensemble des facteurs de production et de conservation, c'est ce que l'on appelle la <u>production fruitière intégrée</u> (OILB/SROP, 1977; Milaire, 1979), laquelle est élargie aux critéres qualitifs des fruits commercialisés. [1]

Eléments de prospective

Comme nous l'avons déja souligné la protection intégrée est essentiellement évolutive et toute innovation, surtout en matière de procédé d'intervention contre les ennemis des vergers, soutient et accélère sa dynamique, notamment en permettant de dépasser la phase de la lutte raisonnée.

Dans les tableaux 3 et 4 nous dressons un relevé des principaux moyens de lutte spécifiques et sélectifs alternatifs à la lutte chimique, en indiquant leur stade d'avancement: recherche, expérimentation positive, application pratique. Pour des raisons évidentes d'efficacité ces mesures concernent le plus souvent les ennemis-clés des vergers, ceux qui sont responsables du plus grand nombre de traitements. En matière de sélection de matériel végétal résistant on donne aussi une certaine priorité aux ennemis qui compromettent l'existence des vergers ou de leur récolte comme le Feu bactérien, maladie provoquée par *Erwinia amylovora* Burr. Winslow et al. ou la Sharka, maladie des prunus due à un virus.

Ce relevé donne une vue plutôt optimiste car en réalité la plupart des méthodes en sont encore au stade de l'expérimentation ou d'une application limitée à quelques régions ou pays. L'analyse de cette situation fait ressortir des causes d'ordre économique, psychologique, structurel, conjoncturel et règlementaire, dont nous donnons ci-après quelques exemples concrets:

- Des variétés hybrides de pommiers résistantes à la Tavelure et tolérantes au Puceron cendré *Dysaphis plantaginea* Pass, à l'Oïdium *Podosphaera leucotricha* Ell. et Ev., voire au Feu bactérien ont été sélectionnées (Lespinasse, 1989, 1990). Sur de telles variétés le nombre de traitements nécessaires est réduit de 80% et on peut passer ainsi de 18 traitements par an en moyenne à 3 (Audemard et al., 1989 ; Audemard, 1991), ce qui diffusé à l'échelle européenne supprimerait l'épandage de milliers de tonnes de fongicides. Pourtant leur diffusion est quasi anecdotique car on n'arrive pas à sortir du cercle vicieux: faible tonnage produit, absence de marché, plantation limitée, sans parler des *a priori* du commerce, par exemple vis-à-vis de la coloration des fruits pour la variété Florina-Querina.

[1]Définition de la production agricole intégrée ou production intégrée (Milaire, 1978 d'après OILB/SROP, 1977) : "Mode de production fondé sur la valorisation des principales composantes de agro-écosystèmes dans le souci d'éviter les dégradations écologiques et d'obtenir des produits agricoles satisfaisant à des impératifs d'ordre qualitatif. La mise en oeuvre simultanée des mesures phytotechniques judicieuses et de la protection intégrée des cultures doit assurer une telle production écologique".

- Les préparations de virus de la granulose permettent de réaliser une lutte microbiologique contre le Carpocapse *Cydia pomonella* L. en vergers de pommiers, poiriers et noyers. Les travaux collectifs, soutenus financièrement par la CCE (Audemard & Cavalloro, 1988), relayés par des essais nationaux, ont montré depuis près de 10 ans l'efficacité de cette méthode et pourtant seulement quelques centaines d'hectares de vergers sont concernés. Les causes en sont : a) la difficulté à intéresser les industriels à la production d'agents biologiques, b) les nécessaires adaptations de la fabrication résultant du changement d'échelle de la production, c) la lenteur à instruire les demandes d'homologation au niveau de la toxicologie, voire l'hostilité de principe des autorités de certains pays vis à vis de l'utilisation des virus d'insecte.

Tableau 4. Moyens de lutte alternatifs à la lutte chimique contre les maladies parasitaires dans les vergers de rosacées fruitières européens

	MALADIE (1)	LUTTE MICROBIOLOGIQUE (ANTAGONISTE PREMUNITION) (2)	MOYEN GENETIQUE (SELECTION) (2)
	MALADIES FONGIQUES		
■	Tavelure du pommier		✡ ✡ ✡
■	Oïdium du pommier		✡ ✡
	Chancre européen à nectria		✡
■	Maladies de conservation des pommes		✡
■	Oïdium du pêcher	✡	✡ ✡
■	Cloque du pêcher		✡
■	Plomb parasitaire du pêcher	✡ ✡ ✡	
	MALADIES BACTERIENNES		
■	Feu bactérien du poirier		✡ ✡
■	Gâle bactérienne du collet	✡ ✡	
■	Bactériose abricotier		✡
	MALADIE A VIRUS		
■	Sharka (abricotier, prunier, pêcher)		✡
	MALADIE A MYCOPLASME		
■	Enroulement chlorotique de l'abricotier	✡	✡

(1) ■ Ennemi-clé

(2) Moyens de lutte:

✡: Stade de la recherche; ✡ ✡: Expérimentation positive; ✡ ✡ ✡: Déjà appliquée;

- La lutte par confusion sexuelle des mâles a bénéficié de la collaboration entre l'industrie, la recherche et les Instituts techniques. Elle n'est pour le moment en Europe appliquée de manière significative que contre la Tordeuse orientale du pêcher. Cependant l'extension à d'autres espèces: Tordeuse de la pelure, Carpocapse des pommes et des poires, Sésie *Synanthedon myopaeformis* Borkh. devrait bientôt intervenir. Les investissements assez lourds en matière de technologie de fabrication (synthèse de phéromone et mise au point de diffuseurs) et de réalisation des expérimentations (superficies importantes, durée) ont indiscutablement freiné l'évolution. Un important soutien technique aux arboriculteurs est requis, au moins au départ, ce qui lie dans une certaine mesure l'extension de la méthode à l'existence de structures de vulgarisation suffisantes.

- Le renforcement de la lutte biologique contre le Psylle du poirier par lâchers de la punaise prédatrice *Anthocoris nemoralis* a démontré expérimentalement son intérêt (Rieux, communication personnelle). Mais il faudra trouver une solution coopérative ou industrielle pour produire cet auxiliaire entomophage à un coût abordable. La lutte biologique par lâchers de parasites contre un ennemi plus occasionnellement dangereux comme le Pou de San José *Quadraspidiotus perniciosus* Comst., qui est cependant un insecte de "quarantaine", a été réalisée avec succès en coopération internationale il y a une vingtaine d'années (Benassy et al., 1968). Aujourd'hui où cette cochenille redevient d'actualité, les structures de production du parasite *Encarsia perniciosi*, de caractère artisanal, (Service de la Protection des Végétaux, Instituts techniques) ne sont plus opérationnelles et il sera difficile d'assurer une pérennité dans ce domaine sans soutien officiel.

Il convient aussi de se préoccuper au niveau des agro-écosystèmes verger, d'autres mesures propres à intensifier l'action des facteurs biotiques participant à la limitation naturelle des ennemis des vergers. Elles concernent les moyens agro-techniques (méthodes culturales comme travail du sol, gestion de l'enherbement, de l'hydro-fertilisation et mode de conduite des arbres). Bien peu d'expérimentations sont réalisées dans ce domaine en raison de la lourdeur des dispositifs et des délais de réponse, qui impliquent des financements d'une durée inusitée pour les décideurs. Un objectif ambitieux est de pouvoir proposer un aménagement de l'environnement végétal du verger, comme la mise en place de haies brise vent composites, en vue de créer des abri-refuges pour l'entomofaune utile autochtone. L'acquisition de références techniques est en cours, mais le "cahier des charges" qu'il faudra respecter pour vaincre les réticences des arboriculteurs est redoutable (concurrence réduite de l'aménagement vis-à-vis du verger, occupation limitée du sol, croissance homogène des arbres et arbustes, résistance au vent, absence de foyer pour les maladies et ravageurs, valorisation éventuelle du bois...).

Enfin l'évaluation des effets des pesticides sur l'entomofaune auxiliaire reste plus que jamais d'actualité, surtout en ce qui concerne les actions à moyen terme. (Hassan et al., 1991).

Discussion - conclusion

Les techniques permettant d'appliquer une lutte (chimique) raisonnée avec des pesticides à moindre incidence écologique, qui est une étape indispensable pour la réalisation par les arboriculteurs d'une protection intégrée des vergers, sont disponibles pour les principales espèces de rosacées fruitières (pommier, poirier, pêcher et nectarinier, prunier, cerisier, abricotier). Dans une vingtaine de régions ou pays de la Communauté européenne ainsi que de l'Autriche et de la Suisse, de remarquables actions ont été mises en place et conduites grâce à une formation adéquate des intervenants, une bonne information des arboriculteurs et le soutien d'organisations souvent bien structurées. Les économies de produits phytosanitaires qui en ont découlé sont généralement de l'ordre de 30%. Il vient s'y ajouter la moindre pollution de l'environnement et la maîtrise de la protection phytosanitaire qui permet d'éviter les impasses techniques, voire le désastre économique.

Les nombres d'exploitations et les surfaces de vergers impliqués sont évidemment très variables, ces dernières pouvant aller jusqu'à 100% du potentiel comme aux Pays Bas. Malgré cela, les superficies qui en ont bénéficié dans les pays précités restent trop limitées. Elles peuvent être estimées à environ 150 000 ha, ce qui ne représente que 15% des surfaces des 6 espèces fruitières et 6,1 % de celles des vergers de toutes les espèces, oliviers et citrus exclus. En d'autres termes, la lutte chimique intensive continue sur près de 1,8 millions d'hectares de vergers.

Cela est d'autant plus regrettable que, dans les régions les plus avancées, on commence à appliquer une protection intégrée, avec une utilisation prioritaire de moyens d'intervention contre les ennemis des vergers faisant appel à des méthodes biologiques, biotechniques et agro-techniques. Ces moyens, de substition à la lutte chimique sont un gage de la sauvegarde de l'environnement.

On peut identifier plusieurs secteurs dans lesquels des mesures et actions sont susceptibles de contribuer à la promotion et au développement de la protection des vergers. On pourrait ainsi:

- Accentuer la dynamique de progrès scientifique et technique par le lancement de programme de recherches et d'expérimentation de longue durée sur : l'intégration des nouveaux moyens de lutte et le fonctionnement des systèmes, la prévision des risques, l'aménagement de l'environnement végétal des vergers, la mise au point de techniques de lutte raisonnée pour les espèces fruitières non encore concernées (noyer, noisetier, chataîgnier, amandier, figuier, petits fruits). Ces espèces couvrent dans les pays précités environ 1 000 000 d'hectares, en faisant abstraction des amandiers en culture extensive.
- Favoriser une association plus étroite entre les industries ou les coopératives, là où cette forme associative s'avèrerait mieux adaptée, et la recherche afin d'améliorer le transfert des technologies à une échelle significative permettant d'assurer la production et la distribution d'agents biologiques, biotechniques et génétiques de lutte.
- Prendre des mesures incitatives dans le domaine de l'utilisation de ces moyens, ce qui peut relever de décisions règlementaires et (ou) économiques.
- Etendre l'activité du réseau européen des Centres de formation pour la protection intégrée des cultures aux productions fruitières, comme le suggère Maurin (1990).
- Favoriser l'information à divers niveaux par l'édition de brochures spécifiques, la réalisation de réseaux de communication, de banques de données et visant des cibles plus diversifiées que les seuls arboriculteurs. Nous pensons aux pépinièristes, distributeurs de produits phytosanitaires et consommateurs. Pour cela des formules d'association avec la presse sont à étudier.
- Soutenir la création d'organisations spécifiques au développement de la protection intégrée en verger et l'action particulière d'Instituts ou Services, comme les Services de la Protection des Végétaux, disposant de conseillers spécialisés.

Certes ces types d'actions sont déjà plus ou moins engagés dans certaines régions, il s'agit maintenant de les généraliser pour en faire le moteur de la promotion d'une protection intégrée et au delà d'une production fruitière intégrée.

Remerciements

De nombreux collègues (41), cités au tableau 2, ont bien voulu effectuer une évaluation de la protection intégrée dans leurs régions ou pays, nous leurs exprimons notre vive gratitude.

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Biological and integrated control in European vineyards

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Summary

The pest and disease situation in European viticulture is described as well as the history and present day use of chemical control. Following, the development of integrated pest and disease control is illustrated. The first step was to develop economic thresholds for all the major insect and mite pests. In order to change from proplylactic sprays against fungal diseases, mathematical models were designed to predict outbreaks resulting in a reduction of sprays.

Three methods of non-chemical control for pests are currently applicable in viticulture: sex pheromones, preparations of the pathogen *Bacillus thuringiensis* and predacious mites. Host plant resistance is widely exploited in viticulture through the use of grafted vines. Mechanical and physical alternatives for herbicides are available. Several other non-chemical alternatives are under investigation:

a. control of the black vine weevil with a fungal insect pathogen,
b. control of powdery mildew with a mycoparasite,
c. several parasitoids and predators of grape berry moth.

The scientific basis for integrated pest and disease management in vineyards has been laid. Continuation along this line will result in further reduction of pesticide usage against insects, nematodes and diseases.

Diseases and pests in viticulture

Viticulture in Europe has always had to contend with a range of fungal diseases and arthropod pests (Table 1). Cane and leaf spot (excoriose), a fungus particularly destructive in cold and wet springs, attacks shoots, leaves and fruits, reducing the vigour and yields of attacked vines. Rotbrenner, though distributed throughout Europe, is only locally important but by attacking leaves and inflorescences may cause severe reduction in yields. Bunch rot (gray mold) causes severe losses, attacking fruit clusters before ripening, thus reducing both the quality and quantity of the crop. In the middle of the last century, two additional fungus diseases of grapevine, powdery mildew and downy mildew were introduced into Europe from North America causing catastrophic losses (Vogt & Götz, 1987).

Several insect and mite pests reduce yield quantity and quality. First generation larvae of grape berry moth destroy whole inflorescences whilst the feeding of second generation larvae promotes a high incidence of bunch rot. The larvae of the tortricid *Sparganothis* destroy young shoots, whilst *Peribatodes* may cause severe losses by feeding on buds in spring. Adults of the black wine weevil also damage buds in spring but the larvae are more destructive, with damage to the root system resulting in the death of the vines (Hillebrand et al., 1990).

The introduction of phylloxera from North America in the last century posed a serious threat to European viticulture. However, the discovery that American rootstocks were resistant to phylloxera paved the way for effective control by using these rootstocks for grafted grapevines in all viticultural regions (Müller, 1930).

Table 1. Major pests and diseases of grapevine in Europe

Scientific name	Common name	Origin
Fungal diseases		
Uncinula necator Burr.	powdery mildew	North America
Plasmopora viticola Berl. et de Toni	downy mildew	North America
Botrytis cinerea Pers.	gray mold	endemic
Phomopsis viticola Sacc.	excoriose	endemic
Pseudopezicula tracheiphila Korf et Zhuang	rotbrenner	endemic
Eutypa lata Tul. a. C. Tul.	Eutypa dieback	endemic
Mites		
Panonychus ulmi Koch	red spider mite	endemic
Tetranychus urticae Koch	two-spotted spider mite	endemic
Eotetranychus carpini Oud.	yellow vine mite	endemic
Calepitrimerus vitis Nal.	grape rust mite	endemic
Colomerus vitis Pgst.	grape erineum mite	endemic
Insects		
Dactylosphaera vitifolii Shimer	grape phylloxera	North America
Empoasca vitis	grape leafhopper	endemic
Coccidae		
Otiorrhynchus sulcatus F.	black vine weevil	endemic
Byctiscus betulae L.		endemic
Sparganothis pilleriana Schiff.		endemic
Peribatodes rhomboidaria Den. et Schiff		endemic
Eupoecilia ambiguella Hb.	grape berry moth	endemic
Lobesia botrana Schiff.	grape berry moth	endemic

A short history of chemical control

Chemical control of grapevine diseases dates back as far as 1848, when for the first time sulphur was used against powdery mildew (Table 2). Copper compounds have remained in use since 1885. Effective control of all the major fungus diseases with the exception of powdery mildew became possible with the introduction of synthetic organic fungicides in 1950 and the instigation of regular spraying programmes. However, soon after the introduction of selective botryticides, problems of resistance arose. The induction of resistance by Benomyl (benzimidazole) led to this botryticide being removed within a few years. The introduction of systemic fungicides against downy mildew has offered the possibility of curative treatments and the option for reduction of preventative spraying (Schruft, 1991).

The recorded history of insect and mite control dates back to 1905 with the use of arsenic, soon to be followed by nicotine. Both of these compounds are highly toxic and their efficiency was depending on favourable climatic conditions. Synthetic insecticides were first introduced in 1939 with Carbazole. Broad spectrum insecticides like DDT and organophosphates were widely utilised in viticulture. A notable landmark in insect pest control came with the introduction of *Bacillus thuringensis,* highly selective for lepidopterous larvae, as a biological insecticide. With the registration of the first synthetic pheromone, mating disruption of the grape berry moth (*Eupoecilia ambiguella*) became an alternative to chemical control (Schruft, 1991).

Table 2. History of chemical control in European viticulture

Compound	Target organisms	First use	Notes
Fungicides			
Sulphur	*Uncinula necator*	1848	First fungicide
Copper derivates	*Plasmopara viticola* *Pseudopezicula tracheiphila*	1885	
Dithiocarbamates	*Plasmopara viticola* *Pseudopezicula tracheiphila*	1950	
Phtalimids	*Plasmopara viticola* *Pseudopezicula tracheiphila* *Phomopsis viticola* *Botrytis cinerea*	1955	
Dichlofluanid	*Plasmopara viticola* *Pseudopezicula tracheiphila* *Botrytis cinerea*	1968	
Benzimidazoles	*Botrytis cinerea*	1971	First selective botryticide
Vinclozolin	*Botrytis cinerea*	1976	
Triadimefon	*Uncinula necator*	1978	Selective against powdery mildew
Aluminiumfosethyl + Folpet	*Plasmopara viticola*	1981	Partly systemic
Metalaxyl + Folpet	*Plasmopara viticola*	1982	Systemic
Insecticides and acaricides			
Arsenic derivates	Insects and mites	1905	Highly toxic
Nicotin	Insects and mites	1908	First synthetic insecticide
Carbazol	Insects	1939	
DDT		1948	
Organophosphates	Insects and mites	1951	
Carbamates	Nematodes,insects and mites	1964	
Bacillus thuringiensis	Lepidoptera	1976	First biological insecticide
z-9-Dodecenylacetate	*Eupoecilia ambiguella*	1986	Synthetic pheromone

Commercial use of pesticides

Hitherto in European viticultural regions, single crops have received as many as 12 annual treatments, comprising various mixtures of fungicides, insecticides and/or acaricides. Furthermore, regular spraying of herbicides have been undertaken to keep the ground free from other plants.

Fungicides

Fungicides are commonly applied as a prophylactic to prevent the infection of the vines by the principal fungus diseases. Spraying programs in Europe vary from 5 - 7 applications in the northern regions to 10-12 in the south. Due to climatic conditions, downy mildew and *Botrytis* bunch rot constitute the main problems in the north whereas powdery mildew extends throughout all areas of viticulture.

Copper compounds are still in use for the control of downy mildew and rotbrenner. However, there use raises potential problems of phytotoxicity and in particular the accumulation of heavy metal residues in the soil. Sulphur is another inorganic substance which is still in use for the control of powdery mildew. Sulphur is most effective when applied early in the season for the control of the first outbreak of powdery mildew.

The advantages associated with organic fungicides have made them the most important substances for the control of fungus diseases. They are significantly less phytotoxic than copper and sulphur and do not effect the bloom.

The control of downy mildew mainly devolves upon dithiocarbamates, benzole-derivates and phtalimids as prophylactic treatments. Acetamids (cymoxanil) penetrate the plant tissue and are therefore efficient even after infection. Treatments with true systemic compounds (phenylamids) are curative and are not washed away by rain although problems have arisen with resistance by downy mildew.

Organic fungicides for the control of powdery mildew are pyrimidin-derivates such as fenamirole, benzol-derivates (dinocap), piperazine-derivates (triforine) and triazoles (triadimefon). Powdery mildew may be resistant to triazoles which inhibit sterole synthesis.

For prevention of *Botrytis* bunch rot, several applications of organic fungicides are usually necessary as well as cultural methods to reduce the susceptibility of the vines. Benzimidazoles were only marketed for a few years due to the rapid appearance of resistant *Botrytis* strains Holz, 1980). Resistance to dicarboxymides, in use as special botryticides, has also been recorded (Leroux & Clerjeau, 1985). Consequently the number of applications of these compounds should be kept to a minimum. An alternative approach is to make use of compounds such as dichlofluanid, which exhibits a side effect on *Botrytis* for the control of downy mildew.

Insecticides and acaricides

Organic insecticides and acaricides commonly in use in viticulture are organophosphates and pyrethroids. Less important although still in use in some countries are carbamates, nitrophenyl-derivates, and chlorinated hydrocarbons. The principal target organisms are the different species of grape berry moth (Tortricidae), mites (Tetranychidae, Eriophyidae) and, especially in the southern viticultural areas, leafhoppers (Typhlocybinae, Deltocephalinae). The frequency of treatments and the inclusion or exclusion of insecticides from standard spraying programs vary from one area to another. Pyrethroids should be avoided in regions were mite control depends on predation by phytoseiid mites which are extremely susceptible to these compounds.

Acaricide resistance in mites is an important problem in places where the same compounds have been used over protracted periods. Resistance of spider mites has been reported for almost all groups of organic acaricides. The use of fungicides such as dinocap, which exhibit side effects on mites or annual changes of acaricides in spraying programs may help to reduce the development of resistance (Englert, 1975).

Herbicides

Many vineyards are kept free of weeds. They are considered undesirable due to possible competition for water, increased risk of frost damage and as potential reservoirs for pests and diseases. In particular the area around the stock becomes difficult to keep clear without the use of herbicides, which are applied both as pre-emergence or post-emergence preparations. The appearance of resistance to triazines (simazine) by members of the genera *Amaranthus, Senecio,* and *Erigeron* has created problems. Troublesome weeds such as *Convolvulus* have also been favoured by the intensive use of herbicides in the past (Kassemeyer & Wohlfahrt, 1989; Moreira, 1990).

Evolution of integrated control

Approximately ninety scientists from seven European countries collaborate in the IOBC/WPRS working-group "Integrated Control in Viticulture". Since 1974, sub-groups have been established to deal with integrated control of insects and mites, fungi and weeds, with appropriate application techniques and culture methods, side effects of pesticides to beneficial organisms and physiological disorders of grapevines (Schmid et al., 1988). Several groups cover problems of risk assessment for grape berry moth, spider mites and fungus diseases.

Economic thresholds

The establishment of economic thresholds for pests and diseases is one of the essential prerequisites for integrated control. Thresholds have been established for all the major insect and mite pests.

Fungus diseases

The continuation of prophylactic applications is essential since there are no fungicides to effectively eliminate specific outbreaks. In consequence downy and powdery mildew cannot be tolerated. Some attack of shoots and leaves by *Botrytis* is acceptable but the inflorescences and clusters should be protected.

An alternative approach to the control of fungus diseases is the use of mathematical modelling for the prediction of significant outbreaks. Models for powdery and downy mildew are available and these forecast disease outbreaks based on recorded climatic data and fungicide applications. For downy mildew, integrated recording and computing equipment is available for installation in vineyards. The output of this kind of systems enables several applications of specific fungicides to be saved by limiting treatment to times of high outbreak risk in areas affected by only one major disease. However, the total number of applications may have to be increased to cope with the control of additional fungus diseases.

Grape berry moth

The interaction between the phenological stage of the vine and the pests or diseases has to be taken into account in the evaluation of economic thresholds. The first generation of the two species of grape berry moth damages inflorescences but only influences yield quality or quantity at high population densities. However, for larvae of the second and third generations of these moths which penetrate the fruit, less infestation can be tolerated due to the danger of secondary *Botrytis* infections.

Different methods have been developed for the monitoring of grape berry moth. The occurrence of two or three distinct generations during the growing season makes it necessary to determine not only the population density but also its developmental stage so that the optimum time for insecticide application can be identified, particularly when non-chemical control methods are to be used.

Female grape berry moth activity can be monitored using bait glasses, and male flight activity with pheromone traps. However, estimates of population density from activity data are prone to be unreliable during unfavourable weather. This in turn influences the reliability of estimating the time of peak oviposition from flight activity. Nevertheless, trapping methods are commonly employed and are readily applied by the growers themselves. The assessment of young larval infestations of the grape berry moth on inflorescences or fruit clusters is more complex but provides a more reliable index than monitoring flight activity. The monitoring of egg deposition enables additional information on the activity of parasitoids to be obtained but is impractical for untrained people.

Spider mites

Economic thresholds for spider mites also change with season. Because of their potential for rapid population increase under favourable conditions and their severe effects on yield quality, lower numbers of spider mites are acceptable in summer at the end of the spraying program than in spring. The level of mite infestation is determined by assessing the mean number of overwintering eggs per node. The activity of natural ennemies can be assessed by estimating the percentage of eggs destroyed. For the assessment of mite population densities per leaf, sufficient samples must be taken to allow for the patchy distribution of spider mites on their hosts.

Non-chemical control

Three methods of non-chemical control of two major pests are currently applicable in viticulture. Sex pheromones and preparations of the pathogenic *Bacillus thuringiensis* are used to control grape berry moth and predaceous phytoseiid mites are conserved or actively disseminated in viticultural areas as excellent control agents for red spider mite. Mechanical and physical alternatives for herbicides are available but not yet applicable in all areas, particularly where cultivation is practiced on steep slopes. Several other non-chemical alternatives are under investigation (Moreira, 1990).

Pheromones

Successful development of mating disruption in grape berry moth provides an example of good effective cooperation between scientists of a chemical manufacturing company and those of the two IOBC/WPRS Working Groups, "Use of Pheromones and other Semiochemicals in Integrated Control" and "Integrated Control in Viticulture".

As in many other species of butterflies and moths, sexual attractants play an important role in the mating behaviour of the grape berry moth. Males follow the pheromone trail left by a receptive female. Rak 1 (Z-9-dodecenyl acetate) was developed by BASF and has been registered for the control of grape berry moth in Germany since 1986. The pheromone is now used at a rate of 50 g active ingredient per hectare. It is distributed by hand at a rate of 500 dispensers per hectare just before the moths of the first generation start to fly. In this way, an artificial pheromone cloud is formed which makes it almost impossible for males to locate females. In consequence only occasional matings occur and the number of fertilized females is significantly reduced (Englert, 1985).

A detailed assessment of the results is essential and should be carried out early enough to allow the use of an insecticide if for any reason the pheromone treatment has failed. The German state governments of Rhineland-Palatinate, Baden-Württemberg and Bavaria recognise the additional work entailed by this method of control in their provision of 40-80 DM per treated hectare for participating growers (Neumann et al., 1986).

Beneficial organisms

Two strategies are possible in the use of beneficial organisms for pest control in viticulture:

a. Microorganisms and parasitoids may be artificially multiplied in culture and released into the field, and
b. predators, like phytoseiid mites may be spread with vine wood or shoots to establish stable populations which protect vineyards from spider mites for several years.

Bacteria. Formulations of *Bacillus thuringiensis* (B.th.) are registered in several countries for the control of grape berry moth. The ingestion of spores by the berry moth larvae is necessary to activate the pathogen which multiplies within the host. Since hatching larvae are highly susceptible whereas later instars inside the fruits are protected from contact with spores, the time of hatching and application must be coordinated precisely for good results. The effectiveness of treatments may be diminished by the occurrence of low temperatures or heavy rain following the application (Steiner, 1983).

Fungi. *Metarhizium anisopliae*, an insect pathogen is under investigation as a non-chemical control agent for the black vine weevil. This troublesome pest in vineyards and nurseries of some northern European areas requires insecticide applications to the soil. Problems in using *M. anisopliae* for control arise due to the microclimatic conditions pertaining in vineyards. During summer, high temperatures and dry soils produce an unfavourable environment for the infection of the beetle with such pathogenic microorganisms (Mohr, 1987).

Ampelomyces quisqualis is a mycoparasite which attacks powdery mildew. Its possible use as a control agent for this disease is currently under investigation. *Trichoderma viridis* is a potential biological control agent for *Botrytis*. However, the first resistant strains of *Botrytis cinerea* were detected in the field shortly before a commercial preparation became available.

Insects. A variable proportion of grape berry moth eggs are parasitized by egg parasitoids of the genus *Trichogramma*. For control experiments, the parasitoid was reared on *Heliothis* eggs and parasitized eggs set out in the vineyards when grape berry moth oviposition was anticipated. Unresolved inconsistencies in the success of these experiments mean that the reliability of *Trichogramma* as a control agent is still questionable (Kast & Hassan, 1986).

Other natural enemies of the grape berry moth include coccinellid and chrysopid larvae as well as other entomophagous insects. These may enhance other non-chemical measures but are unable to maintain this pest below the economic threshold on their own.

Phytoseiid mites. Biological control of spider mites by phytoseiidae furnishes a good example of how chemical methods can be superseded by biological ones. *Typhlodromus pyri* is the most important phytoseiid mite to viticulture acting as a protective predator. It is able to protect vines from spider mite infestation for years. However, its numerical response is too slow to reduce established spider mite populations beneath the economic threshold within a single growing season (Englert & Maixner, 1990).

Female mites overwinter in the bark of the stocks, leaving their hibernacula usually in spring to colonize the young leaves at bud break. *T. pyri* is generally restricted to the undersides of leaves where it can be found close to the veins. A density of one to two postembryonic individuals of *T. pyri* is considered to be sufficient to protect the vine from spider mite infestation. Vines with a high density of *T. pyri* are usually found to be free of spider mites. This situation is achievable since *T. pyri* is polyphagous and can be sustained by other food sources than spider mites. Pollen, perl bodies produced by growing shoots and eriophyid mites furnish the most important additional sources.

The grape erineum mite, which occurs in many vineyards without causing economic loss, is an excellent source of food for *T. pyri*. The predaceous mite reaches significantly higher densities on leaves which are colonized by this mite. Vine growers are therefore able to promote *T. pyri* by tolerating a certain level of erineum mite infestation. The toxic action of wettable sulphur (more than 6 kg per hectare) for the control of powdery mildew on *C. vitis*, causes considerable reduction in *T. pyri* populations in vineyards receiving this treatment.

From results of a large number of field tests, the side effects of pesticides against *T. pyri* are now well documented. This mite is best conserved by restricting treatments to pesticides which do not affect it significantly. Many field populations of *T. pyri* now exhibit resistance to organophosphorous insecticides. In Germany a test for side effects on *T. pyri* is now mandatory for all pesticides before they can be certified for use in viticulture.

Use of resistant grape cultivars

Host resistance is widely exploited in viticulture through the use of grafted vines. The introduction of grape phylloxera into Europe was a serious threat to European viticulture. The problem was solved by the use of American vines resistant or tolerant to phylloxera, as rootstocks. Resistance of rootstocks to nematodes is important in the prevention of spread of nematode transmitted grape viruses. A nematode resistant rootstock variety is now commercially available.

Successful breeding of disease resistant grape cultivars could help solve many of the problems which beset integrated control in viticulture. Cultivars resistant to downy mildew and those exhibiting field resistance to powdery mildew are already available. The wines produced from these varieties are comparable in quality and taste to some new varieties and merit closer scrutiny (Alleweldt, 1984). However, a general demand for traditional varieties of high quality makes it unlikely that they could be replaced in the near future (Kast, 1988).

Application technique

Advanced application technology is an important factor in integrated control. The reduction of pesticide side effects to the environment is improved by using new types of spraying equipment incorporating devices for recycling liquids not deposited on the target. The results of tests with fungicides and insecticides demonstrate that effectiveness is not necessarily reduced by these techniques. Deposition on the soil may be reduced by about 50 % and 30 - 40 % of the total spray volume can on average be saved over a growing season. At present these techniques are restricted to vineyards accessible by tractors. Their application for vineyards on steep terrain could promote a significant improvement in integrated control (Dietzel, 1992).

Side effects on beneficial organisms are also reduced by special application techniques. The restriction of fungicide applications to the 'cluster zone' of the vines preserves an untreated refuge for phytoseiid mites and beneficial insects. In field experiments, Mancozeb and Metiram causing severe toxicity to *T. pyri* when applied with a knapsack sprayer at 700 l/hectare had no significantly harmful effect when sprayed by a helicopter at 150 l/hectare.

Herb cover

Herb cover should be maintained in vineyards except in regions where water is a limiting factor. The advantages of herb cover are widely accepted: less erosion and leaching of nutrients, reduction of chlorosis and stalk necrosis, production of soil organic matter and enhancement of the microbial activity of the soil. Herb cover needs to be managed by regular mowing. Along the trellis lines, the soil is normally kept exposed by mechanical means or herbicides (Mohr, 1987).

Prospects

The scientific basis for a programme of integrated control of diseases, pests and weeds in vineyards has now been laid. Protection of grapevines from losses through downy and powdery mildews and *Botrytis* seem impossible in the immediate future without recourse to chemical fungicides. A better understanding by grape growers of the biology of insects and mites as well as the practice of estimating population densities in the field is of enormous importance in minimizing insecticide and acaricide applications. Therefore, an intensive training scheme for advisers and growers is necessary. The use of herbicides might be reduced considerably if the required machinery for soil and herb layer cultivation could be designed to suit all viticultural conditions.

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Appraisal of integrated pest management systems for controlling insect pests of vegetable crops

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Summary

This review concentrates mainly on describing the progress that has been made with two major pest insects of vegetables, the cabbage root fly (*Delia radicum*) and the carrot fly (*Psila rosae*). It describes how techniques for improved insecticide application and pest forecasting have drastically reduced the amounts of insecticides that need to be applied to crops attacked by these two pests and by certain foliage pests. It also discusses how, by growing cultivars partially resistant to the pests, it is possible to reduce insecticide usage. In situations where only small amounts of insecticides are now required, natural and/or released populations of predators or parasitoids could help even further to reduce insecticide usage by reducing the numbers of pest insects entering subsequent generations. The possibilities of incorporating into future pest management systems microbial agents and chemical repellents unfavourable to the pests are discussed.

Introduction

During the last 30 years the attitude towards pest, disease and weed control in horticultural crops has changed, partly as a result of pressures from conservationists and consumers and, more recently, from organic growers. Since the early 1960s, it has not been sufficient to produce an insecticide only to kill the target organism. Additional information has also been required on the effect of the insecticide on the environment in general, and on beneficial insects in particular. Hence, although the implementation of integrated pest management is slow, progress has to be viewed in light of the vast amounts of information, education and political manoeuvres required to make such systems work.

Integrated pest management

In vegetable growing, two factors operate against the use of "classical" integrated pest management: the transience of the crop due to rotation, and the demand for increasingly high-quality produce. These two factors are complementary as, in the short-term relationship between pest and crop, the natural enemies of the pest have insufficient time to establish their superiority before the crop is damaged and no longer of high quality. Consequently, Dunn & Coaker (1965) suggested that combinations of biological agents and chemical treatments, now commonly referred to as integrated pest management (IPM), had little application when dealing with pests of vegetables. They proposed that rational control was more suitable, since it implied using the existing information on crop culture, pest control and the biology of the pest to determine the minimum amount of the appropriate insecticides to produce the required level of pest control (Dunn & Coaker, 1965).

Unfortunately, during recent years, many authors have defined IPM in extremely loose terms. As a consequence, the editors of a recent multi-authored book on integrated pest management (Burn *et al.*, 1987) in Europe, had considerable difficulty in defining what is now understood by integrated pest management and left it to the readers to form their own opinions. Such a situation is far from satisfactory, as many authors now consider rational control to be synonymous with IPM. Although to some people such differences may appear to be only semantic, I prefer to keep the two approaches separate. Hence, I consider that the "rational" approach is based on using pesticides as the basis of the overall control measures, whereas integrated pest management in the classical sense is biologically-based and uses pesticides only to improve the level of control in those instances where it is essential to avoid large crop losses.

What IPM is already applied commercially?

In preparing this review, I sent a circular to entomological colleagues within the IOBC/WPRS to ascertain how IPM is used commercially in vegetable production in west European countries. With the exception of the work in The Netherlands, which I will describe later, classical IPM in other countries appears still to be largely at the research and development level. I do not find this surprising, as pesticides are not only highly effective control agents but are also relatively cheap. In addition, for many of the biological control agents to be used as a substitute for a particular pesticide, the biological agent often requires a pesticide-free environment and this can rarely be achieved under present field situations, where a particular crop may be subjected to attacks from a wide range of pests and diseases. Therefore, the way to progress initially is to find how to reduce to a minimum the amounts of pesticides required to control the pests and diseases that attack a particular crop. Only after this has been achieved, and it could take many years, will it be possible to obtain a true assessment of the detrimental effects of pesticides on the environment, and to screen adequately biological control agents under truly commercial conditions. It should also be remembered that scientists are currently being asked to develop systems of "natural" control for use in large monocultures which, although now regular features of our landscape, are extremely "unnatural" systems.

For reasons of this type, this review describes how the amounts of insecticide currently applied to vegetable crops can be reduced. The most obvious way to do this is to inspect crops on a routine basis and only apply insecticide when the insect infestation exceeds a pre-determined spray threshold. This strategy is described in detail later in the section on "supervised control".

In addition to methods for reducing the amounts of insecticide applied to vegetable crops, this review also describes how elements normally associated with classical IPM, such as cultural control, microbial control, the augmentation of predators and parasitoids, genetic control, and resistant crop varieties, could possibly be integrated into future systems of pest control. Until we have developed systems that work, there seems little to be gained from attempting cost/benefit analyses, particularly as, at present, no politician seems prepared to put a monetary value on the "protecting the environment" part of the equation.

Case histories - pest insects of brassica and carrot crop

This review concentrates on comparing and contrasting research on the cabbage root fly (*Delia radicum*) and the carrot fly (*Psila rosae*), the two major root-feeding pests of vegetable in the north temperate region. It also includes work on foliage pests of brassica crops, as this situation best illustrates the difficulties facing entomologists attempting to control complexes of pestinsects with reduced amounts of insecticides.

Maggots of the cabbage root fly eat the roots of brassica plants and maggots of the carrot fly eat the roots of carrots. There the similarity ends, as the cabbage root fly is part of a complex pestcontrol system involving about 50 pestinsect species and a great number of pathogens. In contrast, the carrot fly is part of a relatively simple pestcontrol system involving really only the carrot fly, the turnip moth (*Agrotis segetum*), the willow-carrot aphid (*Cavariella aegopodii*) and a few pathogens, one of the most important being cavity spot (*Pythium violae/P. sulcatum*). Hence future attempts at integrated pest management in vegetable crops are more likely to be successful in carrot than brassica crops.

This review emphasises how the amounts of insecticide applied currently to vegetable crops to control the cabbage root fly and the carrot fly could be reduced. Although, for brevity, I will concentrate on pest insect research from the HRI at Wellesbourne, similar lines of research have been, and are being, carried out in most European countries. Detailed descriptions of the specific lines of research adopted by entomologists from the various European countries, and their current progress, can be found in the IOBC/WPRS bulletins produced from the Working Group "Integrated Control in Field Vegetable Crops".

Chemical control

Reducing the amount of insecticide per application

Considerable work has been carried out over the past 30 years to improve the amount of field-applied insecticide reaching the target organism (see Graham Bryce, 1975). With soil-applied insecticides the efforts have been very successful. The trend has been away from broadcast treatments towards types of band treatments, where the chemical becomes more effective because it is localized around the plant roots. In addition, the amount of insecticide can usually be more than halved in spaced crops if the product is applied as a "spot" treatment around the base of the plant rather than as a continuous band (Suett & Thompson, 1985). The most significant reductions, however, have arisen either from treating plants only in the seedbed (Mowat, 1988) or from raising brassica transplants in modules of peat, or other media, and incorporating the insecticide before the modules are formed, or treating the plants *en masse* immediately before planting (Dunne & Coffey, 1988). By adopting this approach, only 20-30% of the insecticide applied in band treatments is required to produce comparable control (Suett & Thompson, 1985).

More effective use of insecticides can also be achieved by improving their placement in the soil. For example, deep distribution of a granular insecticide, using a Matco Verba$^{(R)}$ vertical band applicator during drilling, protected long white radish (*Raphanus sativus*) against cabbage root fly more effectively than a shallowly incorporated, surface band application (Thompson *et al.*, 1986). The precise placement of low-volume liquid insecticide formulations under radish seed at drilling also halved the amount of insecticide required to control cabbage root fly infestations (Thompson *et al.*, 1988). It is likely that the amount of insecticide can be reduced even further by film-coating the seeds (Suett & Thompson, 1985).

Reducing the amount of insecticide applied per treatment may not be appropriate, however, for those insecticides whose breakdown is currently accelerated by the microbial populations present in certain soils (Suett, 1987; Van de Steene & de Smet, 1988; Suett, 1991).

Reducing the number of pesticide applications

Pest forecasting systems.

Practical systems for forecasting the times of attack by cabbage root fly have been devised so that insecticide sprays may be applied to coincide with pest attacks (Finch, 1987). This approach usually reduces the number of insecticide sprays needed per season. Simulation models for forecasting the times of insect attack are generally based on some form of accumulated temperature. The models are devised by determining the pest's rate of development under a range of laboratory conditions, monitoring the pest's activity under field conditions, and finally combining the two approaches. The advantage of using a physiological time scale rather than a fixed calendar date for insecticide application is that 10% oviposition by second and third generation cabbage root fly can vary by as much as 4 weeks from a warm to a cool year. Thus insecticide applied on the mean date could be applied either two weeks early or two weeks late. Such inaccuracy can be avoided by basing the forecast on the appropriate physiological time scale.

The Wellesbourne cabbage root fly forecast is now so well developed that the only data required to produce a forecast for any specific field are daily readings of the local maximum and minimum temperatures and a local soil temperature. This, however, is just the "tip of the iceberg", as the bulk of the information required to develop such systems is biological and this has to be built into the model. For example, it took 15 years to collect the biological information required for the current cabbage root fly model. However, from the experience gained, only 5 years were needed to generate a comparable model for forecasting the timing of attacks by the carrot fly.

A more complex forecasting model, based not only on ambient temperature but also on the amount of rainfall at critical times of year, has been developed for forecasting cutworm attacks in Denmark (Zethner & Esbjerg, 1978; Mikkelsen & Esbjerg, 1983). The present model is now used to generate forecast to advise individual growers in which years, and in which localities, they will have to apply insecticide to prevent cutworms from damaging vegetable crops (Esbjerg, 1992).

Supervised control.

For most brassica crops, insecticides have to be sprayed onto the foliage at some time during crop growth to prevent insect damage reaching unacceptable levels. The number of sprays applied can often be reduced by adopting a system of supervised control (Theunissen, 1984). Supervised control is based on the tolerance of the crop to attack and on the amount of sampling required to determine whether or not sufficient insects are present to merit the application of insecticide. It is also based on the cost of making a wrong decision (risk analysis) and on the normal economic constraints of growing the crop.

According to Theunissen (1984), for pest control decisions to be acceptable to growers in The Netherlands the decisions must be simple and clear. In general, while most growers in The Netherlands are unwilling to count insects, they are, however, willing to search or "scout" their crops to determine the percentage of plants infested with the cabbage aphid (*Brevicoryne brassicae*) and cabbage caterpillars. The "spray thresholds" that are used are based on the tolerance of the crop to cabbage aphid and cabbage caterpillars at given times during the growth of the crop (Theunissen, 1988; Hommes *et al.*, 1988). Although one threshold can be used throughout, fewer sprays of insecticide are required if the threshold is adjusted to match the different stages of plant growth.

Systems of supervised control are now being accepted in commercial practice provided the quality and quantity of the produce remain comparable, and equally reliable, to that from economicallysound insecticide-intensive systems. A list of the countries in which supervised control is now being used, and the crops involved are shown in Table 1. These data were collected by Theunissen at the IOBC/WPRS Working Group "Integrated Control in Field Vegetables" held at Vienna in October 1991.

The incentive for a grower to change an existing practice depends largely upon whether a reasonable economic benefit can be expected from the change. The crux of whether supervised control can generated appreciable savings depends largely upon the amount of insecticide currently applied. For example, in The Netherlands, growers treat crops of Brussels sprouts and red cabbage on average 6.3 times and 7 times respectively. The numbers of sprays could on average be reduced to 5.2 and 4 by adopting a supervised control system (Theunissen, 1984). In England, however, it is rare to apply more than four sprays to Brussels sprouts or cabbage crops and hence savings from supervised control systems may be less feasible. The most crucial point about any system should not be how many sprays can be saved, but how many sprays have to be applied.

Table 1. Overview of development and implementation of supervised control methods in field vegetables in some European countries (After Theunissen, 1992).

Crop	Pests	Country							
		A	B	CH	D	DK	NL	S	UK
Brassica	*Delia spp.*, caterpillars, aphids, diseases		1	2	2	1	2:3		1:2
Carrot	*Psila rosae*	1	2:3	2	2:3	1	3	2:3	
Pea, bean	Pea moth, aphid, midge		1					3	2:3
Lettuce	Aphids							2	
Leek, onion, garlic	Leek moth, thrips, diseases	1	1	1:2	1		1:2		1
Various	*Agrotis* spp. various				2	2		3	2

1 = research; 2 = operational, not yet commercial; 3 = applied by growers

Codes for countries: A Austria, B Belgium, CH Switzerland, D Germany, DK Denmark, NL The Netherlands, S Sweden, UK United Kingdom

For example, if an insecticide that remains at an effective level for 2 weeks is sprayed weekly onto a crop, then reducing the amount of insecticide by 50% involves no risk whatsoever.

Although supervised control can be used when the pest insects can be observed on the foliage of the crop, it cannot be used when the larvae of the insects feed inside the plant, such as pea moth (*Cydia nigricana*) larvae, or on the subterranean part of the plant. In the latter cases, it is usual to develop suitable insect traps so that advisors can use the numbers of adult insects caught to indicate the most appropriate times to spray crops. The traps developed for this purpose include pheromone traps for the pea moth (Wall *et al.*, 1986), the cutworm (Arn *et al.*, 1983), and the diamond-back moth (*Plutella xylostella*) (Rahn, 1988); and coloured traps for the cabbage root fly (Finch & Skinner, 1974) and the carrot fly (Städler, 1969; Brunel & Rabasse, 1975; Freuler *et al.*, 1982; Philipsen, 1988).

In developing supervised control and other pest management systems, it is important from the outset to decide who is going to implement the system. Systems for the extension service or commercial scouts can generally be more complex than ones to be used directly by the grower (Theunissen, 1984).

Cultural control

Crop covers

The cheap lightweight covers developed to allow crops to be established earlier in the season in north temperate regions also keep foliage- and root-feeding pests off crops (Hough-Goldstein, 1987). The placement of plastic covers over about 1,500 ha of carrots drilled during January and February in England to produce early-season crops (J. Blood-Smyth, - personal communication) is particularly effective against carrot fly, as it ensures that the overwintering fly generation does not establish on the seedling crops in the spring. Similarly, a total of about 300 ha of highvalue vegetable crops, such as long white radish, cauliflower and kohlrabi, are currently grown under "crop protecting nets" in Germany. This produce is destined for the fresh market and can demand the premium price, as it is free of both cabbage root fly damage and insecticides (M. Hommes, - personal communication).

Sowing, planting and harvesting times

A common method of protecting crops against cabbage root fly is to vary the times of sowing or planting to ensure that small, and hence highly susceptible host plants, are not present in the field during periods of peak egg-laying activity by the flies (Coaker, 1987). Sowing or planting early in the season allows plants to become sufficiently established to tolerate moderate levels of cabbage root fly attack. Sowing or planting late is also an effective strategy against the carrot fly (Ellis *et al.*, 1987). However, attempts to seed or plant crops late so that they establish in the interval between pest generations usually requires more detailed information on the biology of the pest. For example, with pests that emerge late in certain localities (Finch & Collier, 1983; Finch *et al.*, 1988), delayed planting may increase, rather than decrease, crop damage.

Intercropping

Attempts to reduce pest attacks by increasing intracrop diversity have been made by undersowing plots of Brussels sprouts with either clover (*Trifolium repens*) (O'Donnell & Coaker, 1975) or corn spurrey (*Spergula arvensis*) (Theunissen & den Ouden, 1980). Although the overall effects have been encouraging, it has not always been easy to predict the outcome of any particular intercropping system. Hence, O'Donnell & Coaker (1975) reduced cabbage aphid infestations by 40-90% when 25-100% of the soil was covered by clover, whereas Theunissen & den Ouden (1980) recorded a decrease in aphid numbers only when 100% of the soil was covered with corn spurrey. O'Donnell & Coaker (1975) also showed that the numbers of predatory arthropods were enhanced by the additional shelter provided by the clover and suggested the predators were responsible for the lower survival of cabbage caterpillars (30%) and cabbage root fly (60%). Although this is one explanation, the differences recorded could also result from interference by the intercropped plant during the attraction and oviposition phase of the pest and also for the general influence of the intercrop on the microclimate of the plots (Theunissen & den Ouden, 1980). Irrespective of the mechanisms involved, however, intercropping does produce changes that could form the basis of certain future pest control systems (Theunissen *et al.*, 1992). Its main drawback is that competition from the intercrop often, though not always, reduces crop yields. Such competition may not be considered too important in future, however, if lower yields of good quality produce become accepted on the proviso that the produce is entirely insecticide-free. Like most other alternative methods, intercropping on its own will never provide complete control of pests in brassica crops. For example, although it reduces populations of the cabbage moth and the garden pebble moth, *Evergestis forficalis*, it has no noticeable effect on populations of the small white butterfly (*Pieris rapae*). The latter, however, could easily be controlled by applying sprays of an appropriate preparation of *Bacillus thuringiensis* instead of insecticide.

More recently, mixed cropping experiments involving growing alternate rows of two crops, such as brassica and beans (*Phaseolus* sp.), have also produced some of the benefits of intercropping without severely reducing crop yield (Tukahirwa & Coaker, 1982). This is one aspect that would benefit considerably from additional work, particularly since mixed cropping systems can now be manipulated to produce consistently higher yields than either crop alone, thereby reducing the overall cost per unit of produce (Salter *et al.*, 1985).

Biological control

Intraspecific and interspecific competition

The presence of one pest insect on a plant may influence whether another will select and successfully colonize that plant. Often the insect already present secretes or excretes repellent, alarm or warning chemicals that signal others of the presence of the insect. For example, Klijnstra & Schoonhoven (1987) showed that when females of the large white butterfly (*Pieris brassicae*) laid on brassica plants, they secreted a marking pheromone which deterred other females from laying on the same plant. It was suggested that a reduction of oviposition in cabbage fields might be obtained by spraying this oviposition deterring pheromone onto brassica crops (Klijnstra & Schoonhoven, 1987). An even more striking example of competition occurs between caterpillars of the gardenpebble moth and non-lepidopterous pestinsects (Jones & Finch, 1987). Such caterpillars secrete sinapic acid (Jones *et al.*, 1988) into their frass, a chemical which not only deters other moth species but also pests like the cabbage root fly, from laying on otherwise acceptable brassica plants. Few studies have been made on how one insect species affects another during host-plant selection (Fletcher, 1987). The numbers of biologically derived deterrent chemicals involved in such systems could be prodigious; identification of such chemicals is likely to prove rewarding (Finch, 1989).

Fungi

In the field, the fungus *Entomophthora muscae* regularly kills adults of cabbage root fly. It becomes particularly common following warm moist conditions, when dead, diseased flies can be seen clinging in a characteristic manner to the foliage of many hedgerow plants. A second fungus, *Strongwellsea castrans*, which is characterised by a sunken white body between the abdominal sclerites of infested flies, has at times been found in as many as 90% of the flies caught in water traps (Finch *et al.*, 1981).

Both fungi have been suggested as possible biological control agents for the cabbage root fly (Lamb & Foster, 1986), though the authors clearly recognize the difficulties inherent in this approach. Fungal pathogens, that spread aerially, are usually costly to produce, and individual hosts within a population show a great variation in susceptibility to infection (Burges, 1981). The major constraint with these pathogens is their susceptibility to environmental factors (Eilenberg & Philipsen, 1988), which in broad terms also includes pesticides. A further difficulty in using fungi as potential control agents, is that some pest insects, but not all (Eilenberg, 1987), are not infected until after they have laid the majority of their eggs. The major research effort in trying to use aerial fungal pathogens to control pestinsects in vegetable crop is now being carried out in Denmark (Eilenberg & Philipsen, 1988; Eilenberg *et al.*, 1992).

The current fungal control approach at Wellesbourne is centred on the soil-inhabiting fungus

Metarhizium anisopliae, as this fungus is extremely cheap to produce and strains of it can be selected to kill specific insects in the soil (Chandler, 1992). In addition, its spores remain viable for many months and preparations of it can easily be incorporated into the soil modules currently used commercially for producing brassica transplants.

Bacteria

Attempts to reduce the amounts of insecticide applied to brassica crops in Germany have concentrated on using preparations of *Bacillus thuringiensis* (isolate HD1; var. *kurstaki*) in place of insecticides (Langenbruch, 1984). The caterpillars that commonly infest brassica crops throughout Europe had the following order of susceptibility: *Plutella xylostella* > *Pieris brassicae* = *P. rapae* > *Evergestis forficalis* > *Mamestra brassicae* to this strain of *B. thuringiensis*. Unfortunately, even first-instar *Mamestra* larvae were 12 times more resistant to the preparation than final-instar *Plutella* larvae. Hence, attempts to control *Mamestra* in the field using such preparations will be extremely expensive, unless more virulent strains can be found or new ways can be found to mass-produce the preparations cheaply. As with insecticides, difficulties also arose with hydraulic sprayers in spraying the preparations on to the undersides of the plant leaves. Even though the *B. thuringiensis* isolate was made more effective by adding a wetting agent and a feeding stimulant, the sprays still failed to control the complete range of caterpillars. Similarly, *B. thuringiensis* preparations have to be ingested by the insects in relatively large amounts to be effective and therefore they are generally not effective in the soil. This occurs because root feeding insects tend to tunnel into the plant tissues and hence largely avoid the root surfaces coated with the bacterial preparations.

Nematodes

Morris (1985) suggested that cabbage root fly should be a good candidate for control by nematodes, because its eggs hatch near the soil surface, where the insect larvae could be exposed to nematodes applied as a spray. However, to protect crops effectively, the nematodes would have to be effective against the small first- and intermediate-sized second-instar larvae of the fly, as these instars usually cause most of the crop damage.

The results of experiments testing the effectiveness of nematodes against cabbage root fly larvae have been inconsistent, probably because most experiments have been done under conditions optimal for the nematodes but suboptimal for the insect. For example, Morris (1985) described the susceptibility of third-instar larvae of cabbage root fly to the nematodes *Steinernema feltiae* and *Heterorhabditis bacteriophora* at 25°C in sealed petri dishes containing water, but not food, for the larvae.

In evaluation experiments, nematodes should be tested against the appropriate instar of the test insect at temperatures optimal to the insect, which under UK field conditions would be closer to 15°C than 25°C. In addition, the efficacy of the nematodes should be evaluated under conditions as similar as possible to those of the insects' natural environment, and if possible under field conditions (Theunissen & Fransen, 1984), because environmental factors may influence the efficacy of control. For example, breakdown products from insect-damaged host plants may confer some protection for pest insects by deterring nonadapted organisms, such as polyphagous nematodes, from entering the environment (Finch, 1991).

Even if nematodes can be found that will kill early instars of the cabbage root fly, their use will need to be monitored carefully, as their polyphagous nature could mean they are as, or more, harmful to beneficial ground beetles than the insecticides they are intended to replace.

Parasitoids

In the field, many cabbage root fly pupae are parasitized by the cynipid wasp *Trybliographa rapae* and the staphylinid beetles *Aleochara bilineata* and *A. bipustulata*. European attempts to use parasitoids in biological control systems have concentrated on the beetles. Not only do *Aleochara* larvae parasitize the fly pupae, but under laboratory conditions the adult beetles consume about 10 fly eggs or first-instar larvae each day. Whether they eat these numbers of eggs in the food choice situations available to them in the field remains to be answered. In the field, the beetles emerge after most of the fly eggs have been laid, so growers would have to release the beetles early to capitalize on their predatory behaviour. The beetles would then have to remain near the crop plants for some weeks to be effective as parasitoids. Despite these reservations, attempts are being made to rear *A. bilineata* in numbers sufficient for inundative release (Bromand, 1980; Hertveldt *et al.*, 1984). The numbers of beetles required are somewhat speculative and have been estimated at between 20,000 (Bromand, 1980) and 650,000 (Hertveldt *et al.*, 1984) beetles per hectare. Using the rearing technique described by Whistlecraft *et al.* (1985), 10 hours of labour would be needed to produce 20,000 *Aleochara*. The work, and thus the costs, involved in rearing enough parasitoids to treat large crop areas is daunting.

A possible method for controlling lepidopterous pests with parasitoids is to release into infested brassica fields populations of the egg parasitoid *Trichogramma*. At present, about 60 strains of *Trichogramma* spp. are being reared for this purpose in The Netherlands in the hope that some will prove useful. Before any strain is mass-produced for release, however, it is essential first to establish that the released insects will not adversely affect the natural enemies already operating in the crop (see van Lenteren *et al.*, 1982).

The most important aspects of using *Trichogramma* are that they should parasitize the eggs of all the lepidopterous pests species infesting the plants and that they should be suited to the climatic conditions under which they have to operate. Unfortunately, parasitized eggs of the diamond-back moth (*Plutella xylostella*) have never been found under field conditions in the Netherlands, possibly because the eggs of this moth are too small to be used as hosts. However, damage by diamond-back moth larvae is not serious in the absence of insecticides, largely because both the larvae and pupae of the diamond-back moth are regulated adequately by species of the hymenopterous parasites *Apanteles* spp. and *Diadegma* spp. (van Lenteren & Pak, 1984). At present, it is too early to decide whether *Trichogramma* will ever be useful on a field scale for suppressing populations of lepidopterous pests to the extent required for practical systems of pest control.

Predators

Many (60-100) species of carabid and staphylinid ground beetles are considered important predators of eggs and larvae of cabbage root fly (Hughes, 1959; Coaker & Williams, 1963) and carrot fly (Burn, 1980). Numerous authors have suggested that some of these beetle species could be used to control cabbage root fly directly. However, a factor often overlooked is that not one of the many beetle species preys specifically on cabbage root fly eggs and/or larvae. Despite this fact, laboratory and glasshouse tests have indicated that provided two individuals, of beetles such as *Bembidion tetracolum* and *Agonum dorsale*, can be arrested in the soil adjacent to each brassica plant, they are capable of destroying even high infestations of the pest.

As ground beetles are opportunistic feeders with limited powers of dispersal, their major beneficial effect at present is in maintaining pest populations at more or less constant levels from year to year. For insecticides to be consistently effective at reduced application rates (Suett & Thompson, 1985), it is essential that a healthy ground beetle fauna is maintained, as insecticides all act in a density-independent manner (Thompson *et al.*, 1988).

It has been known for some years that some degree of plant diversity within the agro-ecosystem is fundamental to maintaining a biological component in pest control (van Emden, 1970). As hedgerows, a major overwintering refuge for many key species of polyphagous predators (Sotherton, 1985), have been removed to increase field size for easier management, the environmental diversity has decreased and led to a higher incidence of pest attacks (Speight, 1983). The net effect of hedgerow removal and several other farming practices (Powell *et al.*, 1985; Booij & Noorlander, 1988) is the continuing degradation of the arable environment with a possibly associated reduction in the pest control efficiency of invertebrate predators (El Titi, 1987; Wratten & Thomas, 1990). Currently, attempts are being made to raise predator populations by introducing suitable refuges within crop fields (Wratten & Thomas, 1990) and by studying the total agro-ecosystem to determine the essential elements required to maintain optimum predator populations within any defined locality. The latter is one of the two major aims of the IOBC/WPRS Working Group "Integrated Farming Systems" (see Vereijken & Royle, 1989).

Sterile insects

To control field populations of insects using the sterility principle, attempts can be made to sterilize the insects already in the field or laboratory-reared insects can be sterilized and then released into the natural population.

The former approach was tested against the cabbage root fly in England, to avoid the considerable problems associated with mass-rearing and the release of sterile flies (Finch & Skinner, 1973). Protracted immigration, an innate tendency for females to disperse, reduction in the competitiveness of sterile males, and the failure of males to re-disperse once sterilized appeared to be the main factors limiting the levels of sterility (c. 40% sterility) in cabbage root fly populations exposed to tepa-baited lures in the field (Finch & Skinner, 1973).

The second approach, the release of sterile laboratory-reared flies into field populations was tested in Belgium (Hertveldt *et al.*, 1980). Results indicated that to be effective the ratio of sterile:wild flies in the field should be maintained at about 30:1. In field experiments where 200,000 to 600,000 sterile flies were released onto plots containing 3,000 cauliflower plants, the release of sterile insects was, in practice, no more effective than using baits.

The release of sterile insects, however, is being used commercially for controlling the onion fly, *Delia antiqua*, in certain areas in the Netherlands (Loosjes, 1976 - see Boller, 1987), though much of the success is probably due to the onion plant's resistance to maggots later in the season (Finch *et al.*, 1986). This is one of the few examples of truly integrated pest management in vegetables.

Resistant cultivars

Breeding crops resistant to pest insects is the most obvious method for controlling such pests without using insecticides. Despite concerted efforts during a period at Wellesbourne, little resistance to cabbage root fly attack was found and the resistance identified was not always durable (Crisp *et al.*, 1977). Recently, however, Ellis & Hardman (1988) have shown that partial resistance to cabbage root fly exists in all crops and that moderate resistance occurs in some glossy cabbage and cauliflower lines (Freuler *et al.*, 1990).

In contrast to the slow rate of progress in the work involving cruciferous crops, considerable progress has been made in finding carrot varieties with partial resistance to carrot fly. Workers in the UK (Ellis *et al.*, 1980) and The Netherlands (de Ponti & Freriks, 1980) have concentrated their research on the modern varieties, as stored carrot seed deteriorates rapidly. Hence, many of the older varieties are no longer available as reservoirs of possible resistance genes. Despite such constraints, Ellis *et al.* (1980) showed that the Nantes group was less damaged than the Chantenay and Autumn King groups. The Nantes variety Sytan was the least damaged of those tested, a finding confirmed subsequently in five European countries (Ellis & Hardman 1981).

The early suggestions that resistance to carrot fly could be improved gradually by selection (de Ponti & Freriks, 1980) has not always been substantiated. Consequently, another approach is to make crosses involving commercial carrots and a wild plant parent that has a level of carrot fly resistance much higher than that found in commercial carrots. Hardman & Ellis (1982) identified *Daucus capillifolius* as a resistant wild *Daucus* species, as it did not support appreciable numbers of carrot fly. Crosses made between carrots and *D. capillifolius* (Ellis *et al.*, 1983) produced some "carrot-like" lines at the F_3 and F_4 stage. These are now being evaluated in the field, in the hope that their resistance will be greater than that found in the currently most resistant Nantes-type carrot varieties, which are about 76% less damaged than the most susceptible varieties. This publicly developed breeding material has recently been handed over to allow breeding companies to produce commercial partially resistant varieties.

Integrated control

The advantage of introducing even partially-resistant plants into crop protection schemes is that their resistance is not adversely affected by the presence of insecticides; the two methods are truly compatible and often complementary. It is inevitable under field conditions that, even with highly effective insecticides, some plants will be left unprotected as a result of mis-application (Suett & Thompson, 1985). Similarly, very few resistant cultivars are completely immune to even one insect species. Nevertheless, by combining the two systems, partial resistance can markedly reduce the amount of insecticide required to achieve the desired level of protection. For example, only one-third of the recommended dose of insecticides was required to control carrot fly on a partially resistant variety (Thompson *et al.*, 1980), a strategy that may also help to delay the development of insecticide-resistant biotypes of carrot fly.

Similarly, adequate levels of control of the cabbage root fly and the turnip fly (*Delia floralis*) have recently been achieved in both Scotland (Birch, 1988; McKinlay & Birch, 1992) and Norway (Taksdal, 1992) by using partially resistant varieties of swede (*Brassica napus* var. *napobrassica*) and only 50% of the recommended dose of insecticide.

Conclusions

The successful integration into crop protection systems of methods of pest control that are less environmentally hazardous than insecticides will depend largely on the other pesticides that are applied to protect the crops against other pest insects, pathogens, and weeds. Unless systems involving biological control are carefully integrated with other control measures, benefits from their use could be lost following the inadvertent use of an inappropriate pesticide. Biological control is more suited to crops like carrots in which the pest complex is relatively restricted, and the chance application of an inappropriate pesticide is less likely, than to crops such as crucifers that have a wide range of pests and diseases, several of which may need to be controlled with pesticides in any particular year. The most reliable crop protection strategy in the latter situation is to use selective rather than broad-spectrum pesticides. However, it is not likely that highly selective chemicals will be developed by agrochemical companies, because owing to the small markets the companies would not recoup the costs of product development, let alone make a profit. It is also possible that broad-spectrum chemicals may be advantageous in controlling more than one pest and that an emphasis on greater selectivity may create as many problems as its solves.

Apart from the use of plant resistance, the simplest way to minimize pest damage without using insecticides would be to cover crops at the times of peak immigration of the major pest. However, this would raise the cost of crop protection, as would most other methods involving integrated pest management approaches (Harris *et al.*, 1981). An alternative strategy is to move toward systems of organic crop production, growing the crops out of season to avoid attacks by certain pests and accepting either lower-quality produce or lower yields. Both consequences would raise food prices. Whether or not this would prove acceptable remains to be seen. Whatever happens, the switch from insecticides to alternative methods of pest control is likely to occur slowly unless soil-applied insecticides are no longer effective (Suett, 1987), or no longer available. The biological information required to produce damage-free crops using insecticides is minimal compared to the biological information required to produce a comparable crop with the methods of crop protection currently suggested as alternatives to insecticides. If the era in which we can rely solely on insecticides is drawing to a close (Harris *et al.*, 1981), research on alternative methods of pest control needs to be expanded.

Thus the three major challenges now facing entomologists, pathologists (see Royle & Shaw, 1988) and weed ecologists are: to identify crops suitable for IPM; to gather the vast amounts of information required to apply such systems commercially; and to find ways of presenting the information in a format acceptable to growers.

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Integrated control in olive groves

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Summary

Recent research on bio-ecology, monitoring systems, economic thresholds and non-chemical control of the major olive pests has enabled the agricultural advisory services to introduce integrated control into olive production. Rational control of olive pests relies on the integration of cultural, biological, biotechnical and chemical methods. Cultural control methods include harvesting early to reduce damage by the olive fly, *Dacus oleae*, and on pruning against the black scale, *Saissetia oleae*. In addition, varieties of olives resistant to the olive moth, *Prays oleae*, and to olive leaf spot, *Spilocaea oleagina*, have now been selected. The olive fly can be controlled by inundatively releasing the hymenopterous parasitoid, *Opius concolor*, while the olive moth can be controlled with *Bacillus thuringiensis*. Numerous parasitoids have been introduced into Mediterranean countries to increase the potential for biological control of *Saissetia oleae*. Pheromone traps are excellent tools for determining the correct timing of insecticidal treatments against *Dacus* and *Prays*. In addition mass-trapping involving sex pheromones and feeding attractants can reduce the number of insecticidal sprays required to control the olive fly and in some cases make them completely redundant. Insecticidal bait sprays applied to specific parts of the olive canopy to control *D. oleae* have proved less damaging to beneficial insects than larvicidal cover sprays. The former sprays enable biological control agents to be effective against other pest insects. Integrated pest management programs are now being developed in some olive growing areas in the Mediterranean region.

Introduction

Olive growing is mainly concentrated in the countries of the Mediterranean basin where it represents 98% of the more than 800 million cultivated olive trees in the world, over a surface area of approximately 10 million hectares. The major olive producing countries are Spain, Italy, Greece, Turkey and Tunisia. However, important olive growing areas are found in nearly all other Mediterranean countries. Olive growing in these countries is of great economic and social importance. It enables the exploitation of land otherwise unsuitable for agriculture and provides employment for large numbers of agricultural labourers. The olive plants also help to protect the soil from erosion and now constitute a characteristic element of the Mediterranean landscape.

Widespread cultivation of the olive has in olive groves being planted in many unsuitable areas. In such areas the plants suffer from drought and physiological disorders and produce low yields. In these ecologically unfavourable areas, progressive crop ageing and the difficulty of using cultural techniques because of the rise in production costs and the impossibility to mechanize, favour pest attacks that each year cause important losses both in quality of the olives and in the quantity of the oil. In these marginal areas, pest control methods play an important role in maintaining high crop yields though of necessity the control must be limited to the least costly methods.

In contrast, many olives are cultivated in ecologically suitable environments, where total mechanization is possible and where appropiate cultivation techniques (in some cases including irrigation) ensure a high yield. In this type of intensive olive cultivation, pest control methods are usually applied to maintain high crop yields. However, the excessive use of pesticides can cause serious imbalances in the beneficial entomofauna, leave insecticide residues in the produce and, because of the vastness of the areas treated, considerably pollute local environments.

Olive pests and diseases and their natural enemies

The olive agroecosystem is characterized by a few major pests and many minor or secondary pests (Table 1). A complete list would probably include between 100 and 150 insect species and other pest arthropods. Common in the olive ecosystem are stenophagous and multivoltine species which normally have a high reproduction capacity and no diapause. The most damaging insect, which needs to be controlled in almost all olive growing areas, is the olive fly, *Dacus oleae* (Gmel.). Less important, measured by the frequency and intensity of attacks, are the olive moth, *Prays oleae* Bern., although it is the key insect in some Spanish regions, and the black scale, *Saissetia oleae* (Oliv.).

Table 1. Major olive pests in the Mediterranean basin

Scientific name	Common name
Key pests	
Dacus oleae (Gmel.)	Olive fruit fly
Prays oleae (Bern.)	Olive moth
Saissetia oleae (Oliv.)	Black scale
Spilocaea oleagina Cast.	Olive leaf spot
Major secondary pests	
Parlatoria oleae Colv.	Olive scale
Aspidiotus nerii Bouché	Ivy scale
Liothrips oleae Costa	Olive thrips
Eyphyllura olivina Costa	Olive psylla
Zeuzera pyrina L.	Wood leopard moth
Phloeotribus scarabeiodes Bern.	Olive bark beetle
Capnodium elaeophilum Pril.	Sooty mould
Pseudomonas savastanoi Smith	Olive canker

Several other species of insects cause minor losses, though no economic importance is attached at present to the 13 species of phytophagous mites found in olive trees. Of the many diseases recorded, only olive leaf spot, *Spilocaea oleagina* Cast., is controlled with fungicidal treatments, and this only in areas where climatic factors favour infections.

In addition to the damaging species, there is a large complex of beneficial insects that help to reduce pest numbers. Although some anthocorid, chrysopid and coccinellid predators are common, the most numerous entomophagous insects are the hymenopterous parasitoids, of which 300-400 species have now be recorded (Viggiani, 1989). Practically every olive pest has at least 3-4 natural enemies. For the olive moth, although 40 parasitoid species have been described, only about 10 species occur regularly in the permanent complex of parasitoids (Arambourg & Pralavorio, 1986). The value of naturally occurring predators and parasitoids for the suppression of olive pest populations was discovered as a consequence of the elimination of these natural enemies by insecticides. Reduction in the populations of parasitoids following foliar applications of insecticides to control the olive fly was correlated with severe outbreaks of several scale insects and subsequent increase in damaged fruit and reduced yields (Alexandrakis & Benassy, 1979).

Until the 1950's olive pest control was based essentially on cultural methods and a few chemical methods of uncertain effectiveness. Such chemical methods were mainly bait sprays molasses and sodium arsenite and were applied against the olive fly, though rarely applied over large areas. In the sixties, the availability of cheap synthetic pesticides made it possible to protect the crop efficiently against both pests and diseases. Since then pesticides have come into common use. They are sometimes applied by aircraft over vast areas, and they have improved both the quantity and quality of the product. Resistance to pesticides has never evolved in the olive pests, because the use of pesticides has never reached the high levels of other agroecosystems, mainly because production costs have to be kept low in a cultivation with low returns. However, even after the first few years of application ecological and toxicological side-effects of the insecticidal treatments began to appear. These included: environmental contamination, resulting from the vastness of the areas treated; destruction of non-target organisms, including natural enemies of the pests; severe outbreaks of the olive black scale and other secondary pests; and the presence of insecticide residues in the olive oil, caused mainly by lipophilic pesticides concentrating in this product (Delrio, 1981). This latter problem has become particularly important in recent years due to the emergence of a new group of consumers, who are attracted to the physiological and organoleptic properties of olive oil. Although these consumers are prepared to pay a higher price for olive oil than for other food fats, they also demand a product free from pesticide residues.

In response to the growing need for more efficient, alternative methods of pest control, research has been carried out at international and national levels on bio-ecology, monitoring systems, economic thresholds and non-insecticidal methods of controlling the main olive pests. This research has enabled the agricultural extension services to apply integrated systems of olive production. Great impetus was given to these research programmes by the FAO and EC, who promoted joint ventures in the framework of the Integrated and Biological Control Programme, and by some IOBC/WPRS Working Groups, namely "Biological Control of Olive Pests", "Integrated Pest Control in Olive Growing" and "Fruit Flies of Economic Importance".

Present status of IPM in olive-growing

The basic elements of IPM in olives (biological and environmental monitoring, predictive management models, set of control tactics) were developed interdependently over the last 20 years. The present state of the various components, which are either available or implemented for each pest or which are still in the research phase, are summarized in Table 2.

Biological monitoring

This activity is essential to the pest management process. Without accurate estimates of the population densities of pests and natural enemies and their interactions with the crop, integrated control has no focal point from which to proceed. Methods of monitoring are available for most olive pests, but their accuracy is known only for **some** species. Experiments designed to improve

Table 2. Status of integrated pest management system components in olive growing (+++ available; ++ preliminary data; + on-going research).

IPM system components	Olive fly	Olive moth	Black scale	Olive leaf spot
bio-monitoring	+++	+++	+++	+++
damage threshold	+++	++	+	
predictive model	++			
control methods				
biological	++	++	+++	
cultural	++		+++	
biotechnical	++			
selective chemical	++	++	+	
chemical	+++	+++	+++	+++

the sampling of olive fly infestations have led to a substantial reduction of sampling costs and to standardization of the method that is now applied in Italy for larvicidal treatments. Monitoring adult olive fly populations accurately is essential for control and is based on different trapping systems (Delrio, 1984). In bait-spray control, prompt intervention is essential from early summer onwards, as reproductive females appear when the olives are susceptible to attack. The most suitable monitoring device for this type of control is the McPhail trap baited with protein hydrolysate or ammonium salt solutions. These traps, however, are costly and are being substituted more and more by pheromone traps that are also more efficient and selective. Technical advances have been made in the controlled release of pheromones and these should ensure a more constant release of pheromones over longer periods than previously. Another trap, the yellow sticky trap, for which a good correlation between captured flies and infestation level was demonstrated, is used for the timing of cover spray treatments. Most of the major olive growing countries now operate capture thresholds for spraying against olive fly, though the way they have been derived have not always been the same. Techniques range from 'trial and error' to detailed population studies involving mark and recapture experiments. The use of pheromones and attractants in monitoring olive fly populations is, now well established and progress has been made in improving trap selectivity and efficiency.

Another key pest, the olive moth, is widely monitored with pheromone traps. Such traps can be used both for predicting the period of infestation and for determining the time of treatments to control this pest (Jardak *et al.*, 1984). At present, however, there is no threshold based on pheromone trap captures (Delrio, 1984a).

Damage thresholds

To determine the need for intervention with a specific control measure, it is necessary to know how pest density and duration of pest feeding relate to crop loss. However, these relationships are not yet known for most olive pests. Recent studies on the most damaging species have made it possible to better assess damage which used to be estimated only on the basis of the intensity of the attack. For oil producing varieties there are three potential sources of crop loss due to olive fly attack. These are: a) accelerated fruit fall leading to pre-harvest losses, b) consumption of fruit pulp by the fly larvae reducing the quantity of oil, and c) reduction in the quality of the oil due to increased acidity which decreases the market value (Delrio, 1979).

Not all olives lost in to premature fruit drop constitute damage, because the olive trees can compensate for a 10% fruit drop by increasing the weight and oil content of the remaining olives. While pulp consumption is negligible, the increase in acidity of the oil obtained from infested fruits depends above all on the time drupes remain in the oil mill. The oil quality can be more effectively raised by improving the organization of harvesting and processing than by reducing the fly infestations (Michelakis & Neuenschwander, 1984). The assessment of crop losses caused by this insect has enabled the establishment of precise economic thresholds for some varieties and regions, and practical action thresholds have now been used for some time throughout the Mediterranean basin.

The economic importance of the olive moth has also been assessed for certain small drupe oil producing varieties which induce a high larval mortality during the penetration phase of the young fruit and which compensate for premature fruit drop (Jardak *et al.*, 1986; Niccoli & Tiberi, 1984). The application of the thresholds for the carpophagous generation of olive moth, which is very high (20-50% of attacked fruit), enables substantial reduction or even elimination of control measures for many oil varieties.

Economic thresholds are more difficult to define for indirect pests (e.g., scales), but practical action thresholds have been fixed by expert entomologists (Viggiani, 1989).

Biological control

The conservation and maximum use of naturally occurring biological control agents are traditionally considered very important for the control of olive pests. Various methods of biological control have been studied intensively and in some cases applied successfully.

Efforts are being made to preserve and increase the effectiveness of natural enemies by the judicious use of pesticides. Bait sprays for olive fly control have an important role in reducing the detrimental effects of treatments on beneficial entomofauna, because they allow insecticides to be placed in limited zones and at lower quantities per hectare than cover sprays.

The potential effect of predators and parasites in the control of black scale is generally recognized. To improve the biological control of this pest some hymenopterous parasitoids and a coccinellid predator have been introduced into the Mediterranean area and have established successfully in recent years (Table 3) (Katsoyannos 1984; Mazzone & Viggiani, 1986).

Table 3. Natural enemies of *Saissetia oleae* in Mediterranean olive groves.

Indigenous	**Recently imported**
Chrysoperla carnea (Steph.)	*Rhyzobius forestieri* (Muls.)
Eublemma scitula (Ramb.)	*Metaphycus bartletti* Ann. et Myn.
Exochomus quadripustulatus (L.)	*Metaphycus helvolus* (Comp.)
Chilocorus bipustulatus (L.)	*Metaphycus lounsburyi* (How.)
Lindorus lophantae (Blaisd.)	*Metaphycus swirski* Ann. et Myn.
Moranila californica (How.)	*Diversinervus elegans* (Silv.)
Scutellista cyanea (Motsh.)	*Prococcophagus varius* Silv.
Metaphycus flavus (How.)	*Prococcophagus saissetiae* Ann. et Myn.
Coccophagus lycimnia (Walk.)	
Pyemotes ventricosus (Newpt.)	

For some of the parasitoids (*Metaphycus* sp. and *Diversinervus elegans*) rearing techniques have been developed, that are used by individual growers in France for biological control of the scale. Releases of the parasitoids are calibrated according to the degree of scale infestation (Marro & Panis, 1981; Panis, 1983). Important results have also been obtained with classical biological control against other scales (*Aspidiotus nerii* and *Parlatoria oleae*) (Alexandrakis & Benassy, 1981).

The introduction and establishment of natural enemies of the olive fly must be given high priority because of the expected beneficial long-term effects. However, attempts to establish exotic natural enemies have not yet proved successful. This is probably due to the lack of detailed biological knowledge of the introduced parasitoids and to the low number of individuals released (Delucchi, 1977).

Great efforts have been made in the development of biological control of the olive fly with inundative releases of the braconid *Opius concolor* Szepl. Since 1960 a mass rearing method has been developed for this parasitoid on *Ceratitis capitata* Wied. which can be reared artificially at low costs. Many large scale experiments have shown the efficiency of the inundative releases of *Opius* and the lower costs of biological control compared to chemical control (Genduso, 1981). More recent experiments indicated that *O. concolor* can reinforce or replace chemical control in situations: a) where populations of the olive fly are very high in "hot spots" in early summer, b) where olive fruit remain on the trees until the following spring, and c) in any olive grove, if sufficient parasitoids are available and the groves are not sprayed (Manikas & Tsiroyannis, 1983). Although the use of biological control against *Dacus oleae* has been limited previously by the lack of mass-rearing laboratories, a renewed interest in the application of this method is now emerging. In addition to the rearing of *Opius* by scientific institutions in Spain, Italy and Yugoslavia, a mass-rearing facility, that will cost two million dollars, is in its initial stage of construction in Sardinia.

The side-effects of using chemical insecticides to control *Prays oleae* in olive groves at flowering time have led to a search for more natural methods involving biological control. While at the moment the use of entomophagous insects appears difficult and economically unacceptable, treating the first-generation larvae with *Bacillus thuringiensis* provides good protection against the moth (Yamvrias *et al.*, 1986). Certain countries have progressed from experimental trials to practical applications, especially since new formulations of *B. thuringiensis* enable their use in modern techniques involving low or ultra low volume sprays.

Cultural control

Changes in cropping practice directly affect the dynamics of olive tree/arthropod associations. Irrigation, pruning and fertilization as well as a shift in harvesting dates and changes in pesticide types and patterns of pesticide usage alter both the ecological conditions and the quality of the plant as a host. These changes contribute to fluctuations in pest status and the relative importance of pest species in the olive community.

Although cultural practices are seldom directed intentionally towards the control of insect pests, in some cases they provide the basis for successful integrated control of important pests. Damage by *D. oleae* to oil producing olives can be reduced by harvesting early to avoid the massive attacks in late autumn. This practice, imposed by law by Napoleon I in the last century, is being taken up again in Italy especially following the widespread introduction of mechanical harvesting. Control of black scale can be obtained by shortening the periods between pruning and by thinning out the dense foliage, which protects the crawlers and young settled nymphs from the heat and dryness (Shoemaker *et al.*, 1979). Unfortunately, the use of this method of control involves high labour costs.

Some aspects concerning plantation planning can result in factors favourable for the application of IPM. Infestation of *Dacus* and other pests may be constrained in part by planting more resistant cultivars, avoiding the interplanting of different varieties (in particular large drupe types with those for oil production) and encouraging the natural tendency to alternate yields in old plantations. Field screenings have identified olive genotypes that are relatively resistant, tolerant, or less preferred by particular insects or diseases. These could contribute considerably to the reduction of chemical treatments, e.g. against olive leaf spot (Anton & Laborda, 1989), but the choice of varieties is usually dictated by traditional, agronomic and economic considerations.

Biotechnical control

Methods of control that use pheromones, attractants, repellents, growth regulators and the sterile male technique have been tested against the olive fly (Delrio, 1984). These control methods have not yet reached the stage of practical application for various reasons i.e. the uncertainty of their effectiveness, high costs and organizational difficulties.

Research and development of a mass-trapping system for the control of the olive fly has made particular progress and has recently resulted in large scale application on 2-3 million trees in Greece and 300,000 trees in Sardinia. Attempts to control *D. oleae* by mass-trapping were initiated twenty years ago and were intensified during the last few years due to the discovery of visual and sex attractants and to the development of controlled release formulations for both chemical attractants and insecticides. The most used traps consist of plywood rectangles dipped in a water solution of deltamethrin and baited with a pheromone and an ammonia-releasing dispenser (protein hydrolysate or ammonium bicarbonate salt). Traps are installed in June and placed in each olive tree, or in every other olive tree, and are not replaced during the rest of the season. The application of this mass-trapping system has achieved a reduction or even complete elimination of insecticidal sprays against the olive fruit fly (Haniotakis *et al.*, 1986). This control technique has received considerable approval from growers. However, its application on a wider scale requires technical improvements and the lowering of costs that can only be obtained with the involvement of the commercial industry.

Chemical control

Conventional chemical insecticides have generally provided effective and economical suppression of olive pests. To avoid detrimental effects on beneficial arthropods, pesticides used in integrated programmes should be selective for the target insect. Whereas few insecticides with physiological selectivity, such as chitin synthesis inhibitors (Broumas & Stavraki, 1986) and white oils, are available for use in olive pest control, ecological selectivity that occurred through restricted application of the insecticide has successfully been exploited for olive fly control.

The olive fruit fly can be controlled effectively with curative or larvicidal treatments applied throughout the entire crop canopy using water-soluble and cytotropic phosphoric esters (e.g. dimethoate), once the damage threshold has been exceeded. This type of control has the disadvantage of killing the natural enemies but the advantage that it can be applied effectively by small individual growers. An alternative method is the use of protein baits poisoned with a persistent insecticide, distributed on part of the canopy or on sections of the grove. The advantage of localized bait sprays is mainly in the reduction of insecticides used per ha with consequently less effect on the environmental equilibria (Delrio, 1982). Bait sprays are effective only if the treatment is applied over a short period of time, at the correct time and over vast areas. It thus requires an adequate system for detecting the olive fly adults and an efficient technical support organization. In most Mediterranean countries, bait sprays are applied from the air and are coordinated by central organizations. However, even though these are extremely efficient they are not to be recommended, because they have detrimental effects on the beneficial entomofauna. In Italy, aerial treatments are banned by law and bait sprays must be applied from the ground. Since they are effective only when implemented on a large scale, special organizations are required and this leads to an increase in control costs due to administrative expenses and the need for experts.

Prospects for IPM in olive groves

Implementation of IPM for olives has many of the same problems that have been identified in other agroecosystems. Only a limited number of specific, alternative control methods are available for olive pests, and these are often slower acting, less reliable, or more difficult to use than conventional pesticides. Not all the ideas coming from research laboratories have reached agricultural practice because of various technical and economic difficulties. Progress in IPM implementation will depend as much on modification of the public attitude and expectation as on research advances and new technology.

However, public pressure in the last few years has led many countries to carry out large-scale simplified forms of integrated control in olive groves. The major cost of this must be considered as a social expense and be financed by public organizations. The main features of these programs include: a) systematic scouting during periods of pest risk to monitor crop growth, the extent of damage, insect development, population density and natural enemy activity, b) the use of action-decision rules based on economic injury levels, c) the application of carefully selected pesticides that are effective against the target pest but have the least adverse effects on natural enemies. These supervised control programs have in the past been totally, or partially, financed by National Governments. In recent years, however, a substantial increase of the areas involved has followed the approval of an EC regulation which finances specific programs of integrated control in olive cultivations. In Italy, for example, in 1990 integrated control programs were applied in 9 regions over a total of 180,000 ha. The application of integrated control generally improved production and in some cases resulted in reduction of chemical treatments and an increase in the growers profits, as they were able to sell their oil at higher prices (Cirio & Di Cicco, 1990).

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Biological control in protected crops in Europe

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Summary

Biological pest control is a reliable method and an economically profitable endeavour for growers of greenhouse crops. The fast evaluation and introduction of a number of natural enemies in situations where chemical control was either insufficient, impossible or undesired, has taught crop protection specialists that biological control, within IPM programmes, is a powerful option in pest control. Commercially available natural enemies are listed, current research in biological control is described, biological control in southern and northern Europe is compared, incorrect criticism of biological control is discussed and specific advantages of using this control method in protected crops are given.

Introduction

The total world area covered by greenhouses is small (approximately 150,000 ha), yet developments in biological control and integrated pest management (IPM) in this cropping system have been fast. Greenhouses offer an excellent opportunity to grow high quality products in large quantities on a small surface area. In the Netherlands, for example, only 0.5% of the area in use for agriculture is covered with greenhouses (9300 ha out of 2 million ha). On this small area 17% of the total value of agricultural production is realized, i.e. 3.2 billion US$ in 1988 (van Lenteren, 1990a). Few specialists in biological control anticipated being able to employ natural enemies in greenhouses some 30 years ago, because growing vegetables in this protected situation is rather expensive and pest damage is not tolerated. For ornamentals the situation is even more stringent, because presence of extremely low numbers of pest organisms prevents export, and therefore a zero-tolerance is literally in force.

Successful greenhouse production requires well-trained, intelligent growers who cannot afford to risk any damage from insects for such ideological reasons as biological control being safer for the environment. If chemical control works better they will certainly use it. In tomatoes, for example, pest control represents less than 2% of the total overall cost of production, so pesticide costs are not prohibitive and do not stimulate use of alternatives.

Yet despite the serious constraint that chemical control is so easy and inexpensive, the development and application of integrated control has been remarkably fast. The main reason for developing biological control methods was initially the occurrence of resistance to pesticides in several key pests in greenhouses. Today political forces also influence implementation of biological control (see contribution of Ramakers and others, this volume)

Table 1. World use of biological control in greenhouses since 1970

Year	Pest	Natural enemy		Area under control (ha)
1970	spider mite	predator		295
	whitefly	parasite		115
			Total	410
1980	spider mite	predator		3340
	whitefly	parasite		1180
	leafminers	parasite		40
	aphids	predator		10
			Total	4570
1990	spider mite	predator		7000
	whitefly	parasite		4200
	thrips	predators		1200
	leafminers	parasite		1000
	aphids	predator		350
	soil pests	parasite		50
			Total	13800

Table 2. Commercially produced natural enemies for control of greenhouse pests (after van Lenteren & Woets, 1988 and Ravensberg, 1991)

Natural enemy	Target pest	In use since
Phytoseiulus persimilis	*Tetranychus urticae*	1968
Encarsia formosa	*Trialeurodes vaporariorum*	1970 (1926)
	Bemisia tabaci	1988
Opius pallipes	*Liriomyza bryoniae*	1980-1983*
Amblyseius barkeri	*Thrips tabaci*	1981-1990*
	Frankliniella occidentalis	1986-1990*
Dacnusa sibirica	*Liriomyza bryoniae*	1981
	Liriomyza trifolii	1981
	Liriomyza huidobrensis	1990
Diglyphus isaea	*Liriomyza bryoniae*	1984
	Liriomyza trifolii	1984
	Liriomyza huidobrensis	1990
Bacillus thuringiensis	Lepidoptera	1983
Heterorhabditis spp.	*Otiorrhynchus sulcatus*	1984
Steinernema spp.	Sciaridae	1984
Amblyseius cucumeris	*Thrips tabaci*	1985
	Frankliniella occidentalis	1986
Chrysoperla carnea	aphids	1987
Aphidoletes aphidimyza	aphids	1989
Aphidius matricariae	*Myzus persicae*	1990
Verticillium lecanii	*Trialeurodes vaporariorum*	1990
Orius spp.	*Frankliniella occidentalis*	1991
Verticillium lecanii	aphids	1992

* use terminated, other natural enemy available

History and state of affairs of biological control in greenhouses

Small scale application of biological control in greenhouses was started in 1968 with the use of the predatory mite *Phytoseiulus persimilis*. The whitefly parasite *Encarsia formosa* has been commercially applied since 1970. During the past 20 years, 15 species of natural enemies have been identified and introduced against 18 pest species. Natural enemies in use are insect parasites, arthropod predators and pathogens. The greenhouse area on which biological control is applied has increased from 400 ha in 1970 to almost 14,000 in 1991 (Table 1). Biological pest control further makes the use of bumble bees and honey bees possible as pollinators for some important vegetable crops, particularly tomato.

The natural enemies which have been selected, tested and introduced in programmes for commercial integrated pest control in protected crops are listed in Table 2. Presently, biological control of the two key pests in greenhouses, whitefly (*Trialeurodes vaporariorum*) and spider mite (*Tetranychus urticae*), is applied in more than 20 countries out of 35 countries having a greenhouse industry (Figures 1 and 2). Recent surveys of work on biological control in protected crops can be found in Hussey & Scopes (1985) and van Lenteren & Woets (1988). Details of the developments in this field can be found in the Proceedings of the Working Group on Integrated Control in Glasshouses of the International Organization for Biological Control of Noxious Animals and Plants (Bulletins of IOBC/WPRS from 1970 to 1991; e.g. in Brødsgaard et al., 1990).

At the moment various natural enemies are being tested for use in protected crops (Table 3). The number of companies that produce natural enemies for use in greenhouses has increased from one in 1968 to 30 in 1992.

Table 3. Natural enemies in testing phase (after van Lenteren & Woets, 1988 and Ravensberg, 1991)

Natural enemy	**Target Pest**
pathogens, predators, parasites	thrips spp.
parasites	*Aphis gossypii*
pathogens, predators, parasites	aphid spp.
parasites	leafminer spp.
Aschersonia aleyrodis & Verticillium lecanii	whitefly spp
nuclear polyhedrosis virus	*Spodoptera exigua*
Bacillus thuringiensis	Lepidoptera
nematodes	soil pests
Metarhizium anisopliae	*Otiorrhynchus sulcatus*
Bacillus thuringiensis var. *israelensis*	Sciaridae
mycoparasites/antagonists	leaf pathogens
mycoparasites/antogonists	soil pathogens
Streptomyces spp.	soil pathogens
Trichoderma spp.	soil pathogens

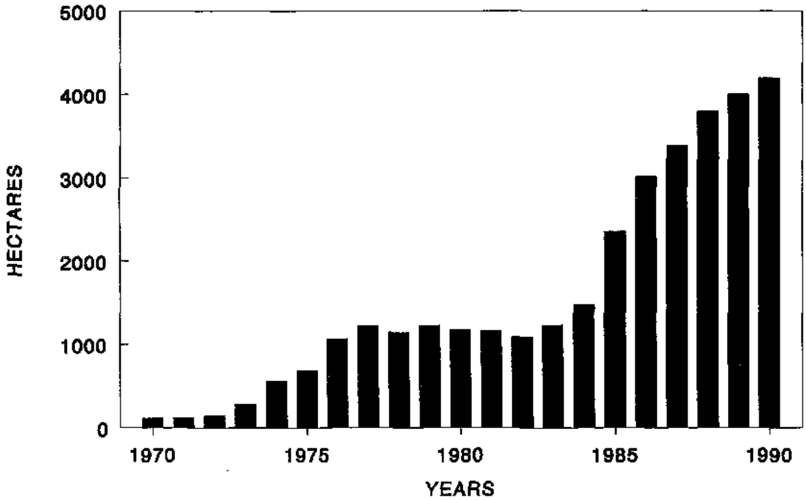

Figure 1. World use of *Phytoseiulus*

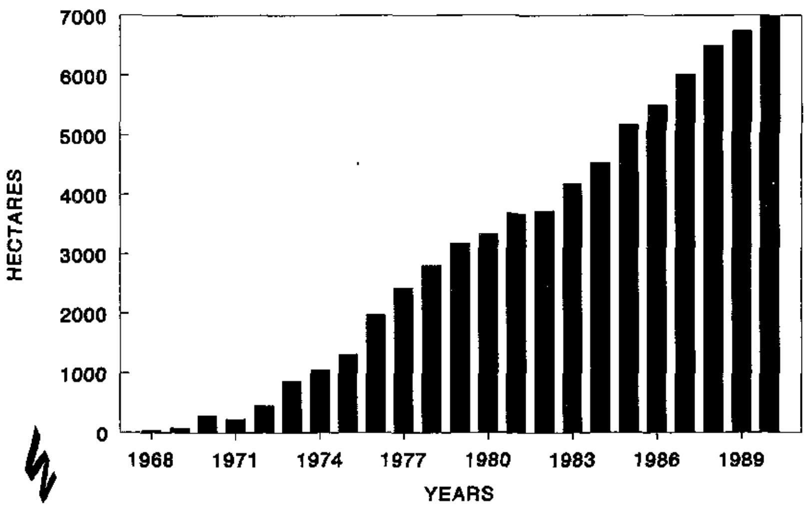

Figure 2. World use of *Encarsia*

Most of the natural enemies mentioned above are employed in integrated pest management programmes, with different regimes of insecticides and natural enemies per crop and per country. The activities of the IOBC/WPRS Working Group on the effects of pesticides on natural enemies, "Pesticides and Beneficial Arthropods", are helpful for selecting those pesticides which interfere as little as possible with natural enemy activity (e.g. Hassan, 1987). Careful guidance on the integrated use of pesticides by producers of natural enemies and advisory staff is essential (see Wardlow, this volume).

The assistance of another working group of the IOBC/WPRS, "Breeding for Resistance to Insects and Mites", may result in important improvements of biological control in the future. For those crops where the population development of the phytophagous insects is so fast that the parasite or predator cannot keep up with the pest, plant breeders search for partially resistant varieties so that population development of the pest is reduced. The first results have been obtained with partial resistance in tomato and cucumber against whitefly and spider mite (de Ponti, 1982)). An unexpected contribution from plant breeding research was to change morphological features of the plant in order to facilitate the searching for hosts by natural enemies. In cucumber, the number of hairs per unit of leaf area has been reduced through a breeding programme, leading to improved parasitization of whitefly by *E. formosa* (van Lenteren & de Ponti, 1990).

Until a few years ago IPM was limited to the control of insects. Several recent initiatives have led to research in non-chemical control of nematodes and fungi. During the most recent meeting of the working group "Integrated Control in Protected Crops under Mediterranean Climate" aspects of this work have been reported, such as: the effect of soil solarization on nematodes and fungi, the role suppressive soils may play in reduction of fungi and the potential use of antagonistic leaf fungi (Garibaldi & Gullino, 1991).

Biological control in northern and southern Europe

Considerable differences in growing protected crops in the Mediterranean Basin and northern Europe strongly influence crop protection measures and, hence, biological control and integrated pest management strategies. First the contrasts in production systems are reviewed and then differences in crop protection measures are discussed.

Protected crops in northern Europe and in Mediterranean Basin

The differences in production in greenhouses between northern and southern Europe can be divided into three categories: greenhouse facilities, climate and management practices.

Greenhouse facilities

The northern European greenhouses are generally built of glass and metal, and often cover an area of 5,000 - 10,000 m^2 on a single holding. In addition, the heating system, which is a part of the computer-controlled overall air conditioning facility, is kept running during the year to provide plants with favourable climatic conditions. Abrupt changes in temperature are avoided, i.e. the overnight minimum often does not drop below 16 - 18° C.; relative humidity is also manipulated.

In contrast, Mediterranean greenhouses are generally constructed of wood and/or metal frameworks, and covered by plastic; they are often movable and rarely exceed a surface of 1,000 m^2. Ornamentals and cut-flowers are usually grown in metal-framed heated glasshouses. Only 10% of the greenhouses in Italy are heated. Furthermore, because most of the protected crops in southern Europe are grown without climatic control, daily temperatures can fluctuate widely, ranging from almost 0° C overnight to more than 25° C during the day in winter and up to 40-45° C in spring and autum. Climatic control is limited to manual opening and closing of the greenhouses and the use of shade screens or whitewashing of the plastic.

Climate

Climatic conditions directly influence pest development as well as greenhouse design and crop choice. The rigid northern european climate with ambient temperatures below 0° C for considerable periods, dictates that glasshouses be so constructed as to keep any contact between inside and outside to a minimum, creating in thus an isolated agroecosystem. For instance, glasshouse openings are installed only on the roof, they may contain insect proof screens and are opened usually when temperatures are high. The low winter temperatures also reduce the growth of weeds around the glasshouse and several pests have a long period of winter diapause (e.g. *Tetranychus urticae*).

The Mediterranean climate on the other hand is mild most of the year, with winter temperatures seldom below 0° C enabling pests to develop year-round even outside the greenhouse (e.g. whitefly and spidermite). This results in a much higher number of pest generations and, hence, a marked increase in the threat they pose. Even within one country differences can be considerable: in the Po Valley (northern Italy) *T. urticae* produces 5 - 8 generations yearly, but on the island of Sicily (southern Italy) more than 30 generations are observed. The mild winter and high summer temperatures force growers to frequently ventilate crops and size and number of greenhouse openings are designated accordingly. This means continuous contact between the greenhouse and the environment even during winter. Contrary to northern Europe, the protected crops cannot be considered as a closed agroecosystem, because arthropods can migrate from field crop to greenhouse and vice versa, depending upon where the most profitable climate exists (Alomar *et al.*, 1989). Another disadvantage is the frequent development of weeds around the greenhouse, which can serve as vehicles for both harmful and beneficial organisms.

Management practices

Here again the differences are large. The horticultural crop cycle in northern Europe is much longer than in the South: transplanting usually takes place in November and cultivation can continue until September - October of the following year. Most vegetable crops are grown in an inert medium (rockwool) so as to prevent problems linked to soil fumigation and post-transplant stress. Another difference is that a grower in the North usually produces a single horticultural crop species, which enables him to manage his operations very efficiently because of a higher degree of specialization and expertise. This expertise also applies to other options such as the choice for the most suitable cultivars and proper fertilization.

The Mediterranean farmer on the other hand, grows several horticultural species in brief cycles of 4-6 months, e.g. a spring (January - June/July) and summer-autumn cycle (July/August - until the first frost or until January, depending upon the latitude). Transplanting in summer (July - September) occurs at the time pest numbers peak, making it difficult to start at low pest infestation levels. This overlapping of seasons and diversity of cropping result in a continuous presence of certain pests. Generally, little attention is paid to farm hygiene: at the end of the season the greenhouse is neglected for the sole reason that it is not thought important to remove the plants. This results in dangerous outbreaks of infestations. Specialization in one or two crops is pursued only in the ornamental sector, whereas no importance is attributed to eventual phytosanitary problems that may derive from improper rotation, resulting in negative effects for the plant protection management system of the farm. It should also be kept in mind that crops are grown in soil and its disinfection is costly and is leading to serious pollution problems.

Main arthropod pests

The pests that pose a threat to protected crops in the Mediterranean Basin are similar to those found in northern Europe (Table 2 and Nucifora, 1989). The most significant difference in the Mediterranean, aside from the infestation intensity, is the greater number of secondary pest species, a fact that may become evident when chemical control is relaxed. Chemical control of these secondary pests causes severe problems in carrying out IPM programmes.

The significance that key pests can have largely depends on the crop, the local climate and the resistance development of the pest populations. Whiteflies are definitively among the most harmful: of these *T. vaporariorum* is the most common species. In the Mediterranean, high temperatures make this whitefly reach very high numbers in many crops. More recently another species, namely *Bemisia tabaci* has spread. It is not only becoming rapidly resistant to pesticides but can also transmit the dangerous tomato yellow leaf curl virus (TYLCV) in tomatoes (Berlinger & Dahan, 1989). Until recently confined to Israel, this virus is now occurring in southern Italy (Credi et al., 1989).

Several species of leafminers occur in greenhouses in Europe: the native *Liriomyza bryoniae*, which is harmful mainly to tomato and *Liriomyza trifolii* which has brought severe damage since its accidental import in the late 1970s from the USA to both horticultural and ornamental crops. Despite frequent application of chemical control; the southern american leafminer, *Liriomyza huidobrensis* invaded Europe recently and is creating severe problems in several crops.

Thrips were not considered a serious threat until a few years ago when western flower thrips, *Frankliniella occidentalis* was accidentally imported from the USA, and has disrupted many IPM programmes. This species also transmits tomato spotted wilt virus (TSWV) that is now causing severe problems on protected crops throughout Europe but particularly outdoors in the South. Other species of thrips, *Thrips tabaci* and *Heliothrips haemorrhoidalis*, cause sporadic harm to vegetables. *F. occidentalis* severely damages sweet pepper, eggplant, cucumber, bean and ornamentals, thereby hindering the expansion of newly launched IPM programmes. Chemical control of western flower thrips is proving very difficult because of ineffectiveness of almost all active compounds of insecticides.

The most serious problems posed by aphids presently come from *Aphis gossypii*. It is especially harmful to cucurbits, eggplant and sweet pepper and has developed populations that are resistant to almost all aphidicides, particularly to pirimicarb employed for its selectivity in IPM programmes. As with *F. occidentalis*, it will be necessary to develop a control system that will enable to resume the IPM efforts so abruptly interrupted. Other common aphids are *Macrosiphum euphorbiae* and *Myzus persicae* which attack tomato, pepper and eggplant, *M. euphorbiae* and *Chaetosiphon fragaefolii* in strawberry and *Aphis fabae*, which is often found in bean and eggplant.

A group of lepidopterous species, particularly noctuids, create problems. It includes *Spodoptera littoralis*, *Chrysodeixis chalcites*, *Mamestra brassicae* and *Heliothis armigera*, all of which are characterized by a marked polyphagy enabling them to attack many different vegetables. Another harmful moth is the European corn borer *Ostrinia nubilalis*, which attacks pepper and bean in some areas.

In several areas (e.g. Po Valley, Italy) Colorado Potato Beetle, *Leptinotarsa decemliniata* can be a severe pest of eggplant.

The most problematic mites species is the two-spotted spider mite *T. urticae*. Its polyphagy and marked tendency to develop resistant populations have caused and still cause severe problems with chemical control in the Mediterranean. The tomato russet mite, *Aculops lycopersici* is also harmful, albeit its attack is confined to tomato (Vacante, 1982), but more dangerous is the broad mite *Polyphagotarsonemus latus*, which infests pepper and certain ornamentals such as gerbera (Nucifora, 1980).

In addition to the pests of the above-ground plant parts, nematodes are very dangerous to the root system. They force growers to disinfect the soil with products having a strong negative impact on the environment.

IPM strategies

The experience gained in northern Europe in the 1960s - 1970s (van Lenteren, 1990b) formed the basis upon which the first IPM strategies were launched in the Mediterranean Basin, although the time-lag was at least fifteen years. The initial trials in Italy were conducted in Sicily around 1980 (Nucifora et al., 1983), though they were preceded by those in France in 1975 (Onillon, 1989). First tests in Greece and Spain date respectively from 1979 (Argyriou, 1989) and 1985 (Castane et al., 1989), and in Portugal from 1987 (Guimares & Sousa, 1989).

The application of IPM strategies encounters problems which can be ascribed to differences in local conditions. The major problem in the Mediterranean is the appearance of secondary pests whenever chemical control pressure is relaxed. This problem was not experienced in northern Europe and other greenhouse areas in temperate climates. Noctuids, myrids and tarsonemid mites are among some of the more familiar examples of such secondary pests. On the other hand, numerous natural enemies can perform in protected crops whenever fewer pesticides are employed and this advantage is definitely greater than what can be achieved in northern Europe: the Mediterranean's more favourable climate extends the period of activity of beneficials and enables them to reach higher population densities. Good examples of this are naturally occurring coccinellids and hoverflies, which can keep aphid population levels below the damage threshold for many months, and myrid predators reducing whitefly populations.

After the development of IPM programmes in most northern European glasshouse areas during 1970s (van Lenteren & Woets, 1988), France, Spain, and Italy are the Mediterranean countries which have also developed IPM strategies, employing the same beneficial species as in northern Europe, in tomato, cucumber, eggplant and pepper. Detailed differences in the use of natural enemies and application techniques between North and South Europe are presented in Benuzzi *et al.*, 1992. The same authors also discuss specific problems of implementing IPM in the Mediterranean.

Targets for research

The role of the entomologist in developing new, non-chemical control methods is challenging: new methods can be exploited (van Lenteren, 1991) and the entomologist can finally play a creative role again after having been in an uncomfortable position for the past 40 years. The targets for entomological work within IPM in protected crops depend on the region where the entomologists are working. In northern Europe, numerous natural enemies are commercially available and the entomologist's task is then to further develop integrated control programmes. Elsewhere they will have to start from scratch. It should be stressed that entomologists should never work in isolation. First they should cooperate with phytopathologists and breeders in order to better coordinate projects. Secondly, they should be in contact with policy makers of the Ministries of Agriculture and Environment, with the extension service and with farmers, to verify that their work is in line with demands from practice. Thirdly, they must develop contact with commercial producers of natural enemies in order to get the biocontrol agents mass produced and distributed.

Historically, the first targets for biological control were organisms resistant to pesticides, such as spider mites. Step-by-step integrated control systems were developed: they are reported in detail in the earlier mentioned IOBC/WPRS bulletins.

Incorrect criticism hampering introduction of biological control

In the following section we discuss often heard, but incorrect, statements about biological control. Such criticism seriously impairs implementation of biological control and IPM.

Biological control creates new pests

Use of biological control against one specific pest is said to lead to new pests, due to a termination of spraying with broad-spectrum pesticides. For the greenhouse situation in temperate zones this criticism is not correct. After the introduction of biological control in 1970 of the key pests, spider mite and greenhouse whitefly, no other pests developed. The pests which have occurred since 1975 were accidental introductions from abroad (e.g. *S. exigua*, *L. trifolii*, *L. huidobrensis*, *F. occidentalis*, *B. tabaci*). These pests have created serious problems in greenhouses both under biological and chemical control. They threatened the biological control of key pests because natural enemies for the new pests could not be found quickly enough. In addition, chemical control of these pests was also difficult because they were already resistant to most pesticides before they were introduced into Europe. Several of these pests are so hard to control chemically that biological control appeared to be the only viable option!

Biological control is unreliable

The idea that biological control is less reliable than chemical control has emerged mainly as a result of strong pressure to market natural enemies before they are fully tested for efficacy. This criticism also arose because some non-professional producers of natural enemies did not check whether the agents they sold were really effective. The philosophy of greenhouse biocontrol workers has always been to only market natural enemies which have proven to be effective under practical conditions within the total control programme.

Natural enemies for which such efficiency studies were performed, e.g. *P. persimilis*, *E. formosa*, and leafminer parasites, have been shown to be just as reliable as, or even better than, chemical control agents.

Biological control research is expensive

Cost-benefit analyses show that biological control research is more cost effective than chemical control (cost-benefit ratio's: 30:1 for biological control and 5:1 for chemical control, e.g. DeBach, 1964; Tisdell, 1990). The fact that despite this, biological control is not used on a larger scale is mainly due to production and distribution aspects of parasites and predators: the whole methodology of natural enemy production is very different from that of pesticides, and shelf life of most natural enemies is short (days or weeks).

It is often thought that finding a natural enemy is more expensive than identifying a new chemical agent. The opposite is usually true: development costs of a natural enemy are on average 2 million US$ and those of a pesticide average 90 million US$.

Application of biological control is expensive for the grower

An important incentive for the use of biological control in greenhouses has been that the costs of natural enemies have been the same or lower than that of chemical pest control. Ramakers (1982) estimated costs (agent and labour) for chemical and biological pest control in 1980. At that time chemical control of whitefly was twice as expensive as biological control with the parasite *E. formosa*. Currently, chemical control of *T. urticae* is almost twice as expensive as biological control with predatory mites (van Lenteren, 1990b). A comparison of costs of biological control and chemical control of other pests is given by van Lenteren (1990a,b). Wardlow (1992, this volume) states that biological control of pests in tomato and cucumber is one fifth to one third of that of chemical control in the U.K. Ramakers (1992, this volume) concludes that even biological control programmes where quite a number of different natural enemies are used (e.g. cucumber), are not more expensive than chemical control programmes.

Practical use of biological control develops very slowly

This criticism has already been disputed above. The developments in use of natural enemies over the period 1970-1988 are given in table 1. The total area now under biological control amounts to 14,000 ha, representing ca 45% of the present potential area for biological control. The method is applied mainly in vegetables, although there has been much recent activity towards developing biological control for ornamental crops. After the initial phase when only *P. persimilis* and *E. formosa* were used, the natural enemy market has considerably diversified.

Specific advantages of biological control in greenhouses.

Why do greenhouse growers use biological control? There are, of course, the general advantages such as reduced exposure of producer and applier to toxic pesticides, the lack of residues on the marketed product and no risk of environmental pollution. These are, however, not of particular concern to the grower. More important are the specific reasons that make growers working in greenhouses prefer biological control:

(a) With biological control there are no phytotoxic effects on young plants, and premature abortion of flowers and fruit does not occur.

(b) Release of natural enemies takes less time and is less unpleasant than applying chemicals in humid and warm greenhouses.

(c) Release of natural enemies usually occurs shortly after the planting period when the grower has plenty of time to check for successful development of natural enemies; thereafter the system is reliable for months with only occasional checks. Chemical control requires continuous attention.

(d) Chemical control of some of the key pests is difficult or impossible because of pesticide resistance.

(e) With biological control there is no safety period between application and harvesting in contrast to chemical control.

(f) Biological control is as cheap as, or even cheaper than chemical control.

(g) Biological control is permanent: once a good natural enemy - always a good natural enemy.
(h) Biological control is appreciated by the general public.

Conclusions: the future of biological control in greenhouses

Several current trends will stimulate the application of biological control in greenhouses. First, fewer new insecticides are becoming available because of skyrocketing costs for development and registration. The few new insecticides that are being developed are not likely to be targeted for greenhouse use because the greenhouse area is small and presents a poor opportunity for chemical companies to recover developmental costs.

Secondly, the recent general use of bumble bees and honey bees for pollination strongly reduces possibilities for chemical control and intensifies demands for biological control. Ramakers (this volume) illustrates that during the first period of biological control in greenhouses the area under biological control increased fast, and that presently the trade volume per surface unit is strongly increasing.

Thirdly, pests continue to develop resistance to insecticides, a particularly prevalent problem in greenhouses where intensive management and repeated insecticide applications exert strong selective pressure on insects.

These three factors result in a greater demand for new pest control methods. It should be realized, however, that a number of conditions have to be met before the technical implementation of biological control becomes a success. Biological control agents should be as cheap, easily available, reliable, constant in quality, and well marketed as chemical control. They should fit well in the total crop protection programme and not be seen as an endeavour separate from other crop protection measures.

Finally, we want to emphasize that biological control should not be seen as a control method that will completely replace chemical control. It is a powerful option and can be applied on a much larger area than done at present. It should be used in combination with other pest control methods, including chemical control, in IPM programmes. This approach is mutually beneficial. For chemical control it may result in extended use of products because of slower development of resistance and a more positive perception of the role of the pesticide industry by public. In order to serve agriculture as well as the environment and human health, we should harvest the best from both approaches to develop effective IPM methods. Designing such environmentally safer IPM programmes is a challenge for our profession.

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More life under glass

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Summary

Biological control methods in glasshouses were first developed to overcome resistance problems, but later dealt also with minor pests interfering with the IPM programs used in practice. In recent years concerns expressed by environmentalists about pesticides contaminating water, soil and air convinced politicians to launch ambitious programmes for reducing the amount of pesticides used. Because of the increasing chemophobia of the public, which was stimulated by the mass media, growers' organisations anticipate a market with more attention to the absence of (even toxicologically acceptable) residues than to effectivity properties. A considerable growth of the trade volume of biocontrol products (overall as well as per grower) in the late eighties has attracted more private investors. The resulting competition did not reduce the prices, but allowed growers to ask for higher quality.

Biocontrol is now common practice in most fruiting vegetables, and there is a beginning interest in application on leafy vegetables because of recent problems with leafminer control. Biocontrol in cut flowers and pot plants is hampered by "zero" tolerance demands for certain insect pests in international trade. It is therefore only feasible if growers produce these flowers and plants for the local market.

Political motivations change crop protection.

Biological control of glasshouse pests was first applied for reasons immediately related to plant protection, such as pesticide resistance and integrated control of simultaneously occurring pests (van Lenteren & Woets, 1988). In the last decade political motivations have become prevalent.

First of all, concerns about the effects of modern plant protection practices on the quality of our environment were translated into actual regulations in many countries. For example the Dutch government has stipulated a reduction of the amount of pesticides used in glasshouses by a factor of three, to be achieved at the end of this century (Anonymous, 1990). Continued stimulation of biocontrol (application in more crops; maximal use of biological components in existing IPM programs) is one of the measurements to achieve this goal.

Secondly, glasshouse crops research is supposed to develop growing systems with minimal output of nutrients and pesticides to the environment. Pesticides in glasshouses are applied as aerial treatments preferable, which produces a detectable output to the outside air. Since glasshouses are usually situated in densely populated areas, these techniques become questionable. As growers do not like the more laborious traditional spraying, biological methods become a more attractive alternative.

Thirdly, the registration of dozens of pesticides is reconsidered on the basis of stricter standards regarding persistence, mobility in soils and aquatic toxicity. This part of the program might become counterproductive, since a number of key chemicals in IPM do not meet the new environmental requirements. Plant protection specialists are trying to convince policy makers to maintain a wide spectrum of selective pesticides to choose from, and focus on the reduction of the actual output to the environment.

Glasshouse vegetables can well be produced with toxicologically acceptable residues. However, the widespread chemophobia propagated by the mass media makes any association of food with residues undesirable. Since two years Dutch auctions offer some IPM products separately to test the response of the market. In this way it would be possible to reward the extra effort IPM growers make.

Recent developments in use of biocontrol in greenhouses

For successful application of IPM massreared beneficials must be available at any time and immediately. In the past many initiatives to start up massrearings have been observed, few of which were persistent. In recent years a more commercial type of enterpriser feels attracted to this market, for obvious reasons:

1. The social and political pressure on copious use of pesticides will make IPM a must rather than just an option. Trade companies involved in plant protection cannot afford to keep away from this part of business.
2. The acreage with IPM is growing steadily (Table 1).
3. An even larger demand for beneficials resulted from a much higher "biological input" per ha (see Tables 2 and 3). Until the mid-eighties most IPM growers used one natural enemy for the price of about Fl. 0.20 per m^2, integrated with a still considerable amount of pesticides. Today growers spend more than Fl. 1.- on various beneficials, thus increasing the trade volume for the producers without proportional growth of the distribution and guidance costs.
4. The successful introduction of bumble-bees for pollinating crops, particularly tomatoes (Table 3), required the massproduction of these insects, and forced more biocontrol to be applied. Since bumble-bees save labour (hand-pollination), growers are paying more for biocontrol than they would be prepared to spend on these agents, were they not used in combination with bumble-bees.

   The total trade in beneficial arthropods (biocontrol + biopollination) for glasshouses in the Netherlands is estimated at Fl. 35 million this year.

Table 1. Development of biological pest control in West European greenhouses (ha) in recent years

Source describing: **Year**	van Lenteren & Woets, 1988 1985	Wardlow, 1990 (except *) 1988	Ravensberg, 1992 1990
Target pest			
whitefly	1,260	2,080	3,200
spider mite	990	1,460	2,900
thrips	65	800 *	1,100
leafminers	460	510	900
aphids	80	40	250

Table 2. Direct costs of IPM in fruiting vegetables grown under glass in Fl/m² per year *

		Cucumber 3 plantings	Tomato round	Sweet Pepper red
Total yield		78.0	76.1	85.4
Biocontrol				
Target	**Agent**			
spider mite	*Phytoseiulus*	.24		.24
whitefly	*Encarsia*	.28	.20	
thrips	*Amblyseius*	.51		.32
thrips	*Orius*	.10		.10
aphids	*Aphidius* + *Aphidoletes*	.07		.28
leafminers	*Dacnusa*		.22	
noctuids	*Bacillus*	.02	.04	.04
Total Biocontrol		1.22	.46	.98
Chemical control				
insecticides		.57	.46	.22
acaricide		.46	.16	.11
fungicides		.75	.27	.04
Total pesticides		1.78	.89	.37
Bio./ (bio. + chem.)		41 %	34 %	73 %

*Estimates by extension service (Anonymous, 1981)

The future of biocontrol in greenhouses

The fiercer competition between massrearing companies did not result in reduction of costs for the growers. Growers try to profit from it otherwise, for example by raising their quality demands. Prices for biocontrol are still similar to prices for pesticides, and the same holds for bumble-bees versus hand-pollination. Obviously the choice for IPM is not primarily cost-related. Rather it applies that glasshouse growers can afford the input of expensive materials such as biocontrol agents (as well as modern pesticides).

Plant protection is - just like medicine - an area susceptible to wishful thinking and superstition. Because of the growing complexity of IPM as well as the presence of competing companies in this field, the need of objective and independent information is increasing. Economy measures affecting advisory services are therefore a cause for concern.

Table 3. Commercial use of beneficial arthropods in Dutch glasshouses.

	Cucumber	Tomato	Pepper
IPM acreage today (ha)	600	1,000	500
Direct costs (Fl/m^2)			
biocontrol	1.20	.42	.94
pollination			
bumble-bees		1.53	.16
honey-bees			.10
Total	1.20	1.95	1.20
Increase rate since 1985			
acreage	1	1	9
turnover/ha	7	9	7

Other obstacles for continuation and expansion of IPM include:

- Lack of tolerance for even slight cosmetic damage in the trade channels.
- Zero tolerance for insects in international trade, affecting the feasibility of IPM in ornamentals particularly.
- Lack of selective insecticides. Present registration procedures seem to be paralyzed by the attempt to exclude any conceivable risk. It should be stressed that this is not necessarily advantageous for IPM, since it blocks the development of sophisticated chemicals with a narrow activity spectrum as well as microbial preparates.

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Integrated crop protection and biological control in cereals in Western Europe

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Summary

Analysis of the present status of cereal production shows a general trend to higher yields and intensification of plant protection measures.

Resistant varieties against fungal diseases are widely used and the mixture of cultivars or lines for disease and pest suppression and stabilization of yield proves to be very efficient. Practical use of cultivar mixtures, however, is yet limited. Several computer based decision systems for diseases, pests and weeds have been developed and the use of pesticides can now be based on the application of economic thresholds. However, the acceptance and use of decision-support systems is yet very limited.

Comparisons of high and low input production systems of wheat show that the financial results of those with a reduced input of nitrogen, pesticides and growth regulators are equal to systems with a high input of chemicals.

Maize is one of the few field crops where mostly only herbicides are applied. Combining row treatments of herbicides with mechanical weeding is an effective and practical means to reduce pesticide application and to prevent the build up of resistant weed populations. Fungal diseases are controlled mainly by resistant varieties, seed dressing and plant density. A good example of effective biological control in field crops is the use of *Trichogramma*, a parasitic wasp of the European corn borer, the key pest in maize. The reasons for the limited use of such methods are discussed.

Introduction

Intensive use of pesticides in cereals has become common practice and, at present, an end to the increasing application of chemicals is not yet envisaged. To obtain high yields, modern varieties are grown with more nitrogen input and partly as a consequence more plant growth regulators and fungicides against diseases are used. As a result, farmers are locked in an endless spiral of intensification. To escape this, alternatives are urgently needed. Are there technical and political options in Western Europe to reduce the use of chemicals in cereals without forcing the farmers into economic difficulties? What are the new developments in cereal growing and how far can integrated plant protection and biological control offer solutions for an environmentally safer plant protection? These questions will be discussed hereafter.

Cereal growing in Western Europe

Cereals are grown in Western Europe on a total area of approximately 42 million hectares. This is 52% of the total arable land. Area and production data in Table 1 refer to crops for dry grain only (FAO, 1989). Both in terms of area and grain production, wheat and barley predominate (80%). The total area of maize harvested for silage, green feed or corn-cob-mix is about equal or even higher than that for dry grain. In Europe, 11% of the world cereal production comes from only 6% of the world's cereal acreage, indicating a highly intensive cultivation. Likewise, the differences between the countries within the EC are very distinct with, for instance wheat production in The Netherlands amounting to 7900 kg/ha compared to Portugal with 1800 kg/ha in

1989. This demonstrates that the natural conditions (climate, water, soil) require different cultivation systems. Therefore, high yields with high inputs of fertilizers and pesticides do not form a general rule in Western Europe. However, it applies for countries of the central and north-western part.

Average yields of cereals from 1965 to 1989 are presented in Figure 1. Dry grain yields increased by 50% to 100% depending on the cereal crop. Maize and wheat, showing the steepest slopes, are above the average yields of the total cereals.

Table 1. Cereal growing area in Western Europe (countries of EC[1] and EFTA) in 1988 and grain production in 1989 (FAO, 1989)

	Area harvested (x 1000 ha)	% of Arable land	% of Cereals	grain production	
				tonnes x 1000	in %
Arable land	80 050	100			
Cereals total	41 590	52	100	190 606	100
Wheat	17 451	21.8	42	87 488	45.9
Barley	15 048	18.8	36.2	57 754	30.3
Rye	1 682	2.1	4	6 131	3.2
Oats	2 837	3.5	6.8	8 653	4.5
Others (rice, sorghum, millet)	435	0.5	1	2 346	1.2
Maize	4 265	5.3	10.3	28 400	14.9

[1]) former Democratic Republic of Germany included

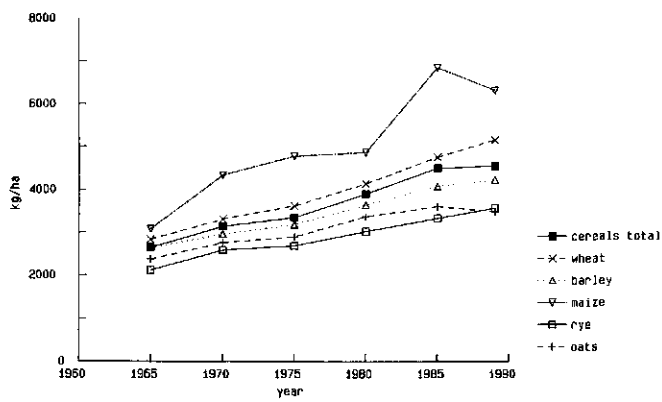

Figure 1. Average yields of cereals (kg/ha) in the EC and EFTA from 1965-1989 (fromer DDR included)

Table 2

	Cultural methods: rotation	sowing periods	sowing density	straw and stubble destruction	volunteers and weed destruction	tillage	resistant varieties	mixture of varieties	reduced nitrogen	certificat. of seeds	Chemical methods: seed dressing	soil pesticides	foliage, ear pesticides
Insects													
Aelia spp.													●
Agriotes spp.	◑		◑								●	●	
Chlorops pumilionis		◑			○								◑
Cnephasia pumicana													◑
Contarinia tritici	○												●
Eurygaster spp.													●
Oscinella frit		◑	◑		○	○	○				◑		◑
Oulema spp.		○					○						●
Sitodiplosis mosellana	○												●
S. avenae, M. dirhodum, R. padi		○					○	○	○				●
Slugs	◑			◑		◑						●	
Virus													
Barley yellow dwarf virus		◑			◑		○						●
Nematoda													
Heterodera avenae	●				○		◑					○	
Diseases													
Gerlachia nivale	○	○	○	○					○		●		
Pseudocercosporella herpotrichoides	●	○		○	◑	○	◑						●
Gaeumannomyces graminis	●			◑	◑								
Erysiphe graminis		○	○		◑		◑	○	◑		◑		●
Helminthosp. teres	◑			○	◑	◑	◑				●		●
Puccinia striiformis		○			◑		◑		○				●
Puccinia recondita		○			◑		◑						●
Drechslera graminea		○								●	●		
Septoria nodorum	○		○	○		○	◑				●		●
Tilletia caries		○					○			●	●		
Ustilago nuda										●	●		
Weeds	●		○	◑	◑	◑						◑	●

Table 2: Present status of effective control methods against the main pests, diseases and weeds in small grain cereals in Western Europe (Application of control method: 0 = not used, ◑ = used to some extent, occasionally, ● = commonly used)

During this period a tendency of decreasing rye and oats acreages can be seen (2.2 to 1.7 and 4.4 to 2.8 million hectares, respectively), whereas the area of maize is increasing (3.3 to 4.3 million hectares) and area of barley and wheat is rather stable.

Present status of crop protection in cereals

Cereals are cultivated in many different ways. Crop protection measures vary between countries and regions depending on the natural resources, the structure of the farms, the market situation and the knowledge of the farmers. A discussion of the status of plant protection in cereal crops can therefore only be an attempt to draw some general lines with the help of a few, well documented cases. An overview of the possibilities and use of control methods against the major pests, diseases and weeds is presented in Table 2.

Small grain cereals

Cultural methods

From Table 2 it becomes evident that, besides chemical control, an array of cultural control methods are available for use to prevent pests, diseases and weeds in cereal crops.

Crop rotation. Cereals are traditionally grown in rotation with other arable crops. Table 2 shows that it is a commonly used and efficient method to control particularly soil born diseases, nematodes and weeds.

Sowing period. A careful choice of the sowing time within its possible limits can be an extremely efficient method to prevent pest establishment at a susceptible stage of the crop and subsequent crop loss. A well documented example is the gout fly, *Chlorops pumilionis* which attacks young wheat, barley and rye plants in early autumn.

Sowing wheat and barley before mid-October in Central and Western Europe increases the risk of attack by the frit fly, *Oscinella frit*, and cereal aphids which may transmit barley yellow dwarf virus (BYDV) (Lapierre et al., 1977; Empson & Gair, 1982; Huth & Lauenstein, 1991). In Spain and other southern European countries, primary virus infections transmitted by migrating aphids occur till the end of November (Pons & Albajes, 1987).

Straw and stubble destruction after harvest. This will reduce slug populations and the risk of infection of several diseases.

Destruction of volunteers and weeds. Grass-weeds and volunteer cereals can act as carriers of diseases and pests. The couchgrass, *Agropyron repens*, is a host of the fungus *Gaeumannomyces graminis* which causes take-all disease. This grass-weed can carry over the pathogen from one cereal crop to the other and largely nullify the controlling effect of crop rotation. Volunteer cereals may become troublesome, particularly where cereals are grown intensively. When they survive, they transmit also foliage diseases as yellow rust, *Puccinia striiformis*, brown rust, *Puccinia recondita*, and powdery mildew, *Erysiphe graminis* (Roberts, 1982).

Resistant varieties. Breeding for disease resistance has been for decades an important activity for most cereal breeders in Western Europe. In spite of their efforts, they did not succeed to control all diseases and pests in breeding new cultivars, because most resistances used broke down, as soon as they were exposed to the pathogens for a certain time. Another reason why breeding for disease resistance did not yet manage is that breeding for durable resistance requires a much higher input than the conventional use of major genes. The results of our two experiments in 1990 illustrate the boom and bust cycle (Figure 2). Generally spoken, "newer" cultivars yield equally with and without application of pesticides whereas "older" (10-year old!) cultivars (which have lost their resistance) yield significantly less if they are not protected by pesticides.

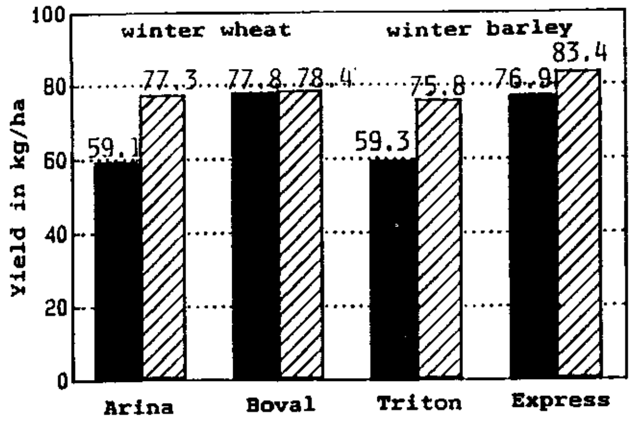

Figure 2. Yield of 2 "older" varieties (Arina and Triton) and 2 "newer" varieties (Boval and Express) without and with protection with plant growth regulation and fungicides; 2 locations 1990. Total N application: 120 kg/ha.

Breeding for resistance against insect pests is still neglected (Dixon, 1989). Different degrees of resistance are reported in wheat against cereal aphids (Sunderland et al., 1988; Hanson & Charpentier, 1988) and intensive research is carried out to get better understanding of the underlying mechanisms (Thackray, 1990; Niraz & Dabrowsky, 1990). Resistance mechanisms against frit fly exist in oats (Jonasson, 1988) and in winter barley (Bigler et al., 1989). Economic loss caused by frit fly is reported from Germany and chemical treatments are recommended (Volkmar & Stark, 1991). The same effect, however, is obtained when two-rowed winter barley varieties are cultivated instead of the six-rowed varieties which are 5-6 times more susceptible (Bigler et al., 1989).

Chemical methods

Although, cultural control methods form the basis of preventive crop protection in cereals, chemical control has become increasingly important in many EC and EFTA countries during the past decade.

Table 2 shows that nearly all pests, diseases and weeds which can be controlled by pesticides. Pesticide use in cereals was rather occasional before 1970. Since 1975 a steady increase is observed and pesticide applications have become common practice nowadays in many countries (Daamen, 1990; Hildebrandt et al., 1991).

The absolute number of treatments per season is very variable between countries, regions and years. The German survey may serve as illustration. Between 1977 and 1987, average pesticide treatments increased from 5.6 to 11.2 in areas with high intensity cultivation. In extensive wheat growing areas it increased from 2.3 to 4.1 treatments per season, or when averaged over the whole country, an increase from 3.4 to 6.8 applications was observed.

A rough idea of the differences between the countries in EC and EFTA is presented in Table 3. The figures are the result of an inquiry which we have sent to plant protection advisors in the seven countries listed. The data show that weed control is almost exclusively done by use of herbicides. Literature data indicate that the situation in other countries as Great Britain, Spain and Italy is almost similar (Hardy, 1986; Camaret, 1990; Camaret et al., 1991).

Table 3. Use of pesticides in small grain cereals in six countries of Western Europe in 1989/1990. (Figures are derived from questionnaires sent to plant protection advisors)

	Area of cereals with use of (%)				**Pesticide applications[2] (#)**				
	herb.	fung.[1]	insect.	plant growth regul.	herb.	fung.	insect.	plant growth regul.	total
Belgium	100	98	70	80	2	1.6	1	0.8	5.4
Denmark	100	90	15	15	1.5	1.4	0.15	0.15	3.2
France	96	80	50	60	1.3	2	0.6	0.6	4.5
Germany Lower Saxony	95	85	15	50	1.5	1.8	0.35	0.5	4.15
Germany Bavaria	85	80	15	50	1.1	1.2	0.15	0.5	2.95
Netherlands	100	95	98	90	1.4	1.3	0.9	0.9	4.5
Switzerland	95	60	15	70	1.2	0.8	0.15	0.7	2.85

[1]) seed dressing not included
[2]) average of treated and untreated area

Table 4. Yield of winter wheat (kg/ha) and number of pesticide treatments per season in six important cereal production areas in the EC from 1985-1989 (Camaret et al., 1990)

Region	**Fyen (Denmark)**	**Lower Saxony (Germany)**	**East Anglia (UK)**	**Ile de France (France)**	**Plain of Po (Italy)**	**Castile-Leon (Spain)**
Yield (kg/ha)	7200	7220	6920	7250	6700	2700
Herbicides	1*	1	2	1	1	2
Fungicides	5*	3	3	3	1	0
Insecti-sides	2*	1	1	1	1	0
Growth regulators	0	1	1	1	2	0
# Total	8*	6	7	6	5	2

*) reduced, split doses for each treatment

Fungicides are widely used on cereals but between countries and regions it varies between 60 and 100% of the cereal area treated. The differences in insecticide use between countries is striking. The total treated area varies from 15% to 98% and the average number of treatments from 0.15 to 1 per season. Growth regulators are approximately in the same range as insecticides. It must be pointed out that great differences exist between cereal crops: generally wheat is the crop with the highest input of pesticides, followed by winter barley, rye, spring barley and oats.

Figures on average yields and pesticide treatments in winter wheat from six important cereal growing areas are summarized in Table 4 (Camaret et al., 1990). Averages from 1985-89 are quite similar in five out of the six areas. However, yields and pesticide use in Castile-Leon are much lower due to the production system in dry conditions. The mean number of pesticide treatments including plant growth regulators varies from 2-8. The differences are due mainly to the fungicide treatments which vary according to rainfall and humidity in summer.

Maize

Table 5 summarizes the general status of plant protection in maize in western Europe. Instead of discussing the whole table, we would like to present the status of biological control of the European corn borer, *Ostrinia nubilalis*, the most important insect pest of maize in Europe and north America (Hudon et al., 1989).

Biological control of the corn borer has been a major research subject in several European countries during the last 10-20 years. *Bacillus thuringiensis* (Bt) has been used on small areas but with rather unsatisfactory results. The efficiency varies from 20-60%, so at present, Bt treatments in maize are applied rarely. Since 1970, much effort has been devoted to study the use of the egg parasitoid *Trichogramma evanescens* as biological control agent.

This tiny wasp had been applied previously against this pest in USSR and Bulgaria. After the first commercial introductions in Germany and Switzerland in 1978 (Bigler, 1986; Stein, 1987; Bigler et al., 1989) a steady increase of the treated area could be observed (Table 6). In 1991 approximately 20,000 ha were treated with the parasitoid, which is 5% of the 380,000 ha treated with insecticides in France alone. Despite the increased use of biological control insecticides are still commonly used to control corn borer. Liquid pyrethroids which kill also the beneficial insects were used on more than 250,000 ha in 1991. In many cases the balance between natural enemies and pests was destroyed and, as a consequence, aphids became injurious (Naibo & Foulgocq, 1983; Mestres & Cabanettes, 1985; Leisner et al., 1987; Ohnesorge, 1988; Katz, 1991). Moreover, high aphid populations on maize in late summer and autumn can endanger winter cereals because these aphids migrate to young cereal crops and may infect them with BYDV. Although, the average efficacy of *T. evanescens* is generally between 75% and 95% (Bigler, 1986; Hassan et al., 1990; Bigler et al., 1989; Frandon & Kabiri, 1990), the wasps are still used on limited areas.
Corn borer control with *T. evanescens* has several advantages compared to insecticides:

1. high efficacy;
2. no toxic effects to humans;
3. no environmental pollution;
4. harmless to the fauna (especially to natural enemies of pests);
5. simple and quick application (no special equipment for hand release needed, labour 20 minutes per person, per ha);
6. no drift problems by areal release;
7. no registration needed (in most countries).

Table 5

	Cultural methods								Biological methods		Chemical methods				
	rotation	sowing period	sowing density	mechanical weeding pre-emergence	mechanical weeding post-emergence	tillage, stubble destruction	choice of cultivars	potash fertilizer	Trichogramma	BT	seed dressing	soil application row	soil application broad	foliage apll. row	foliage apll. broad
Insects															
Ostrinia nubilalis	○					◐	◐		◐	◐					●
Sesamia spp.						◐	○								◐
Noctuidae					○							○		○	●
Agriotes spp.	◐		○			◐					●	●	◐		
Oscinella frit		○					○				●	●		○	◐
Diseases															
Seed rots, seedling diseases	○	◐	○								●				
Root and stalk rots	○		○			○	●	◐							
Puccinia sorghi					○	○									○
Ustilago maydis	○					○	◐								
Ear rots	○					○	◐								
Helminthosporium spp.	○					○	◐				●				
Weeds	◐			○	◐	◐								◐	●

Table 5: Present status of effective control methods against the main pests, diseases and weeds in maize in Western Europe (Application of control method: 0 = not used, ◐ = used to some extent, occasionally, ● = commonly used, BT = *Bacillus thuringiensis*)

Table 6. Area treated with the egg parasitoid, *Trichogramma evanescens* (= *T. brassicae* = *T. maidis*) in countries of the EC and EFTA against the European corn borer, *Ostrinia nubilalis* in maize (1978 - 1991).

Year	Area (in ha) commercially treated with *T. evanescens* in:					Area (in ha) treated with insecticides in France
	Austria	France	Germany	Switzerland	total	
1978			30	150	180	
1980	-[1]	-[1]	300	360	660	500 000[2]
1985	500	500	2 300	2 700	6 000	500 000[2]
1988	200*	3 200	3 800	3 700	10 900	550 000
1989	150*	6 850	3 900	3 750	14 650	500 000
1990	150*	7 700	4 100	3 800	15 750	430 000
1991	175*	10 000	5 100	3 900	19 175	380 000

*) sweet maize
[1]) experimental areas only
[2]) estimation by UNCAA and AGPM, Paris

The data were supplied by the following services. Austria: Biologische Bundesanstalt für Pflanzenschutz, Vienna; France: UNCAA (Union National des Coopératives Agricoles d'Approvisionnement) and AGPM (Association Générale des Producteurs de Maïs), Paris; Germany: BBA Institut für Biologische Schädlingsbekämpfung, Darmstadt; Switzerland: NWV (Nordwestverband Landwirtschäftlicher Genossenschaften), Basle

Despite these advantages of the wasps, they are not applied on large areas because of:

1. high price
2. traditions of the farmers
3. insufficient information and knowledge of the farmers
4. inadequate promotion by government's advisors

The price is considered to be the most important handicap for the use of the wasp. The prices vary, as for the pesticides, between the countries. In France, the price for the product amounted in 1990 between FF 250.- and 300.-/ha. The cost for liquid pyrethroids treated by aircraft (equipment and labour included) was approximately FF 250.-/ha. In Germany, the price for the product alone was DM 170.-/ha. The complete treatment with a liquid pyrethroid was approximately DM 100.- only. In Switzerland, only micro-granulated insecticides are registered against the corn borer and their ground application needs special, expensive equipment. The cost for one hectare treatment is approximately SFr. 280.- whereas for the wasp it amounts to SFr. 150.-. Labour costs for two *Trichogramma* releases per season (together about 1 hour/ha) are SFr. 25.-. Thus, at present Switzerland is the only country where biological control of the corn borer is cheaper than chemical control. About 100 tonnes of micro-granulated insecticides are saved yearly because of the application of *T. evanescens* on 4000 ha maize.In order to promote biological control, some German counties (Bundesländer) are subsidizing the use of *T. evanescens* by DM 100.-/ha which is more or less the difference with chemical control. Since then a considerable increase of the treated acrage was observed.

Computer based forecasting systems

The uncertainty of pest and disease outbreaks led to an intensive research on forecasting methods and risk assessment during the last three decades. At first, the main objective was to identify critical situations to prevent yield losses by timely using pesticides. Today, the major aim is to reduce pesticide use and estimate the economics of pesticide applications. A comprehensive disease or pest forecasting system should estimate the future state of crop diseases or pests, the crop damage and evaluate the situation with a cost/benefit analysis. The main point of a forecast system for the farmer is to reduce his uncertainty in taking control decisions and to support his decision. From the biological differences a broad spectrum of decision-support systems (DSS) can be deduced: Royle (1990) outlined seven main characteristics of DSS, which concern the spatial and temporal operating scale, whether one or more harmful organisms or a crop or even a farm managment system is focused, the extent of utilization of environmental and biological monitoring, the incorporation of cost/benefit analysis, and the role of computers in their operation.

Examples of decision support systems

In many European countries leaflets or publications (Obst, 1989) with indications of action thresholds are distributed by the extension services. With increasing complexity, computer facilities are needed to handle the data in an efficient way.

CERCOPROG. An example of a computer sustained DSS is the CERCOPROG system which supports the farmers in the decision of eyespot control of winter wheat. With data from about 80 weather stations in the western part of Germany and infection probability is calculated (Obst, 1988). The CERCOPROG system is developed by Schrödter & Fehrmann (1971) an is improved by Weihofen et al. (1986). Apart from the meterological data, this system takes several agronomic factors into account.

EPIPRE. EPIPRE is a DSS which reaches a rather high level according to the classification of Royle (1990). It is a computer-based supervised control system for diseases (eyespot, rusts, mildew and Septoria) and aphids in winter wheat, developed in The Netherlands (Rabbinge & Rijsdijk, 1983). The farmers must make observations on diseases and pests according to a standardized procedure. For the prognosis of *Septoria nodorum* he also should make record of rain precipitation on his farm (Forrer, 1989). The data are fed into a computer which calculates the future development of diseases and aphids and the corresponding yield losses. For this prediction basic crop data e.g. variety, yield expectation, and field characteristics as well as variable agronomic factors as the input of growth regulators and nitrogen fertilizers are taken into account. The calculated loss is compared with the cost of pesticide applications. Since we assume that most of the treatments have also negative side effects (e.g. build-up of pesticide resistance, reduction of beneficial organisms and microorganisms) in the Swiss version of EPIPRE secundary costs of SFr. 100.-/ha (corresponding to 100 kg wheat) are added to the costs of the pesticide treatments. These are recommended only if the estimated yield benefit is greater than the costs.

EPIPRE is the only DSS that had an international impact. Beside The Netherlands, EPIPRE was or is in use in Belgium, Switzerland and to some extent in Sweden. In Switzerland, the implementation of EPIPRE was performed by our research station together with the extension services. After a 4-year period of testing (1981 to 1984), in 1989 already 1000 farmers followed the recommendations of our DSS's. From 1984 (year of introduction of the eyespot model and a new Septoria model) until 1990 we evaluated EPIPRE in more than 180 field trials (Table 7). The results showed that the wheat yields obtained with EPIPRE were about 2% lower than those treated according to the conventional spray scheme. Comparison between the cost corrected gross return of EPIPRE and the conventional procedure showed that no difference existed in the financial result of both systems. However following the EPIPRE-procedure, more than one third of the conventional sprays could be saved without loosing a substantial amount of the total wheat production.

Expert systems for plant protection in cereals

Advances in computer technology have made it possible to develop expert systems. Expert systems are computer software applications capable of performing reasoning and analysis functions in defined subject areas at levels approaching that of a human expert. An important advantage of expert systems is that they enable the user to follow the reasoning behind the decision-making pathways (Royle, 1990). The ICI wheat COUNSELLOR is an example of a commercial DSS for control of diseases in winter wheat. The system was mainly developed for use by ICI distributors and had problems to reach the operational phase. However, it would have an enormous value as a data base for depicting disease and pest histories of specific fields (Royle, 1990). In Germany recently two comprehensive expert systems for cereal diseases have been developed: The Weizenmodell BAYERN will be accessible on VIDEOTEX and is being tested since 1990 (Stephan, 1990). The expert system PRO_PLANT is designed for PC-use and should come into practical use in 1991/1992 (Frahm et al., 1990).

What are the reasons for the limited use of DSS in cereal production?

Table 8 gives an estimation of the impact of DSS in seven countries of Western Europe. The figures are from questionnaires which have been sent to plant protection advisors in the different countries in 1991.

Table 7. Comparison of fungicide use and yields in field trials treated according to a conventional spray scheme and EPIPRE in Switzerland 1984-1990

Year	trials (#)	Mean # of treatments		Yield		Corrected gross return*	
		E	C	E (kg/ha)	C %	E (SFr./ha)	C %
1984	49	0.6	1.4	7080	102	7300	99
1985	45	1.2	1.6	6880	102	6870	100
1986	35	1.4	1.8	6280	101	6080	100
1987	23	1.4	1.8	6050	101	5760	99
1988	19	1.6	2.1	7100	104	6800	102
1989	4	0.8	2.0	6990	102	6940	99
1990	6	0.7	1.5	7130	101	7190	99
84-90	-	1.1	1.75	6790	102	6710	100

*) Gross return minus costs for product, machinery, labour and secondary costs
E = EPIPRE C = Conventional C % = C in % of E

Table 8. Use of decision-support systems (DSS) in seven countries of Western Europe in 1991 (Figures derived from questionnaires sent to plant protection advisors)

Country/Region	**Acreage (in 1000 ha) resp. percent of cereals with use of DDS for:**			
	weeds	diseases	insects	System used
Belgium	- / 0 %	0.95 / 0.3 %	0.95 / 0.3 %	EPIPRE
Denmark	75 / 5 %	- / 0 %	- / 0 %	PC-weed control
France	- / 0 %	- / 0 %	- / 0 %	-
Germany Lower Saxony	60 / 4 %	12 / 1 %	12 / 1 %	a, b, c
Germany Bavaria	25 / 2 %	? / 0 %	? / 0 %	HERBEXPERT (Hoechst)
Italy	- / 0 %	- / 0 %	- / 0 %	-
The Netherlands	2 / 2 %	2 / 2 %	2 / 2 %	EPIPRE
Switzerland	- / 0 %	2.4 / 1 %	2 / 1 %	EPIPRE HORDEPROG

a) Göttingen count system, b) CERCOPROG, c) aphid warning system

The data show clearly that DSS have only little impact in cereal growing. Possibly the low figures in Table 8 may be somewhat misleading since they do not give the overall impact of DSS in plant protection. These systems are often used for the information of farmers and extension workers. Farmers who have learned to observe diseases and pests make generally a more effective use of pesticides by chosing the right one or even by deciding that a treatment is not necessary. But why do not they use DSS more often?

DSS such as EPIPRE have several inconveniences:

1. DSS are, at least at short-term, economically not interesting.
2. Field observations are laborious. So why should the farmer choose this way if he makes the same benefit without using EPIPRE?
3. The diagnosis of diseases is difficult, particularly for foot diseases and blotch diseases as e.g. Septorioses. If on-site support by a skilled expert is not available, the farmer soon gets uncertain and chooses the way with the lower risk, which is a fixed spraying scheme.

From our experience with EPIPRE we can assume that in wheat growing in Switzerland 0.5 to 1.0 tonnes of fungicides per 1000 ha could be saved using EPIPRE. With DSS's taking diseases, and also pests and weeds into account, savings of 1 to 2 tonnes per 1000 ha are likely. If we assume that the same extent of pesticide reduction is realistic for the total wheat production in Western Europe, we estimate that on 175 million ha of cereals, 175,000 to 350,000 tonnes of pesticides could be saved!

Future developments of crop protection in cereals

In Table 9 we have tried to summarize some criteria and measures that are being used or which in our opinion could be used in the future in small grain production in Western Europe. Our vision might be somewhat optimistic but to serve society as a whole we think that such concepts should be discussed and evaluated by industry and governmental agencies.

Strategies for breeding resistant varieties

The use of "natural" resistance genes in pure lines or mixtures will become more complicated and require a higher input. For example, although variety mixtures are known to bring higher yields over many years (Wolfe et al., 1991) or to increase yield and quality stability (Fried et al., 1991), little use of this strategy has been made in practice. The costs of development, registration, seed production and marketing of variety mixtures, (also valid for breeding line mixtures or multilines) are still considered to be too high in comparison to the production of pure line varieties with race-specific resistance.

As to the development of race-nonspecific (durable) resistance little is undertaken on the practical front. Winzeler et al. (1991) report on a method to breed lines which could help to break the boon and bust cycle of race-specific resistance. In a first step, the frequency of the virulence genes in the powdery mildew population is determined. A race without virulence genes is used in the laboratory to identify wheat breeding lines which have no major genes. These lines are then taken to the field, inoculated with the most virulent isolates available and those with the lowest disease severity are then selected and used. Other criteria and control measures, and their possible impact in the future are presented in Table 9.

New developments of decision supported systems

The ideal DSS should have the following characteristics:

- comprehensive and covering all important aspects of plant protection
- easy to use and to access, but not labourious
- adaptive to each situation and changing production conditions
- self explaining
- accurate, reliable and quick in response

It should also taken in mind that DSS must be implemented in agriculture, permanently actualized and supported by farmers and extension services.

EPIPRE is a first step in the outlined direction. Expert systems can be a further step. The incorporation of several models for weeds, diseases and pests in a comprehensive crop or farm management system could be the next. CERA, a prototype for such a system, was recently developed in The Netherlands (R.A. Daamen,pers.communication). CERA is a computerized advisory system for cereal cropping (e.g. including fertilization, selection of cultivars and EPIPRE).

New developments may reduce uncertainty in the diagnosis of plant diseases relevant for DSS. A first step in this direction is a microscopic method for the detection of *Pseudocercosporella herpotrichoides* according to Wolf & Krüger (1981) and the "BAYER cereal diagnosis system" according to Verreet/Hoffmann (Mauler, 1990). Both methods promise a good estimate of the actual quantity of inoculum but are too labourious for large scale use.

Much more promising seems the use of ELISA (Enzyme-Linked Immunosorbent Assay). Unger et al.(1990) showed that about 70% of the usual eyespot treatments could be saved by using ELISA. An eyespot ELISA kit that can be handled by the farmer is in production by Du Pont de Nemours (Smith et al., 1990). ELISA kits with monoclonal antibodies for the detection of *Septoria nodorum* and *Septoria tritici* have been developed by AGRI-DIAGNOSTICS and CIBA-GEIGY. With these on-site tests, results are available within 10 minutes (Mittermeier et al., 1990). However, for use in DSS, the Septoria tests should not only be qualitative but also quantitative. Diagnostics are not only very valuable for DSS purposes but also for the selection of resistant varieties.

Table 9. List of criteria and control measures to produce small grain cereals at present and in the future

Criterium/control measures	Present	Future
Virulence survey of diseases on a countrywide or continental basis	Except for barley mildew, only local surveys or nonexistent	Access to information is important
Comprehensive gene mapping of cereals	First steps are made	Markers available
Crosses	Mainly "blackbox" activity, trying to make complementary combinations	Directed crosses with the possibility to control if a character has been transferred
Gene deployment	Not used today. New varieties are bred, used for a short time, then discarded → mismanagement	Care is taken to avoid breakdown of resistance, that is the use of specific genes in multilines, variety and breeding line mixtures
Breeding for race-specific resistance	Widely used. Resistance often breaks down rapidly	Use for extended period of time in variety or line mixtures possible
Breeding for field or race-nonspecific resistance or durable resistance	Except for resistances which are quantitatively inherited e.g. against *S. nodorum* or *S. tritici* or for adult plant resistance genes against rusts, little is done in practical breeding	Input will increase; varieties with tolerable amounts of disease will result. Low levels of disease will be economically acceptable. Change of forecasting systems like EPIPRE
Gene transfer	Not possible yet	Will be possible, but expression in new genotype has to be checked. New gene deployment strategies can be developed and used
Registration of varieties	In most countries the performance with and without pesticides is evaluated	Only the performance without use of pesticides decides upon registration. Susceptible varieties are withdrawn
Diagnostics	Are now being developed for many diseases	Allows a more accurate decision and a more exact therapy (timing and dosage)
Induced resistance	First positive results under laboratory conditions	Probably a useful method with low environmental risks
Chemical control	Widely used to guarantee high yields	In near future, variety specific recommendation which respects different levels of the cultivars will be developed. Use of fungicides will be reduced. Direct financial support alleviates farmer's loss in income.
Plant growth regulators	Widely used in intensive production systems	Cultivars with better lodging resistance will prevail and make their use unnecessary.

Table 9 (continued)

Criterium/control measures	Present	Future
Herbicides	Widely used, also with a view on crop rotation	Replaced partly by mechanical control. Potential relatively high in Integrated Farming Systems
Insecticides	Only locally of certain importance	Natural control will in most cases keep the pests under the threshold level
Fertilization with N	Appropriate fertilization based on soil analysis e.g. N-min and removal by the crop is used in only a small part of cereals (< 5% in 1990)	More exact application rates based on fast analytical methods for mobilization of N in the soil. Possibly strong regulation by governments.

What is the role of DSS in IPM and ecologically orientated cereal production systems?
So far DSS are mainly used to give intensive cereal production an "integrated" touch. However, extensive use of integrated methods (e.g. rotation, reduced nitrogen input, variety mixtures, mechanical weed control etc.) will lead to a lower pressure of harmful organisms. This provides opportunities to reduce the intensity of monitoring. Diagnostics may promote the use of DSS and make the system more reliable. With the right combination of IP-methods and DSS it seems realistic to save 60-75% of the currently used chemicals in cereal production.

Mechanical weeding
Weed control in cereals is accomplished almost exclusively by herbicides. The earlier-mentioned survey about pesticide use among plant protection advisors shows that an average of 1.4 and 1.3 herbicide treatments per season are applied in small grain cereals and maize, respectively, and that 90-100% of the cereal acreage is treated at least once per season. These figures demonstrate the importance of herbicides but also the urgency to reduce their use. A reduction or banning of herbicides in general, and of specific compounds especially, has recently been implemented by new legislation in several countries. Consequently, new methods of weed control are urgently needed. Mechanical weeding alone or combined with reduced dosage of herbicides has been intensively investigated in the past years. The results regarding efficiency and costs look promising. Irla & Ammon (1991) compared yields and costs of mechanical and chemical weed control in winter and spring wheat and winter barley in Switzerland. Part of the data are summarized in Table 10. The authors conclude that in most situations the efficacy of mechanical weeding is high enough to prevent yield loss. However, in heavy soils and wet periods, the risk of weed problems is higher and then it is recommended to apply reduced dossages of herbicides. In conclusion, mechanical weeding of small grain cereals is a promising way of reducing herbicide use and merits promotion in the future.

Our survey also reveals that less than 1% of maize is grown without the use of herbicides. There is some evidence that this situation will change in the near future. Many weeds became resistant against for instance Atrazin during the past 10 years and, as a consequence, more expensive herbicide combinations have to be applied. Future weed control strategies were discussed by Ammon (1986) and Ammon & Niggli (1990). Recently, new laws were issued limiting or prohibiting the use of Atrazin in maize because of water pollution. Similar problems exist with the use of nitrogen fertilizers. Closely connected to weed control is the protection of the soil from water erosion and compaction.

The multitude of complex problems has initiated new systems approaches in maize cultivation. The major aims are: 1. minimizing herbicide use, 2. prevent (further) build-up of resistant weeds, 3. minimizing leaching of nitrate into ground water, 4. protecting the soil from erosion and compaction. In order to achieve the goals, a permanent cover of the soil either by green or dead plants is appropriate. Some of the proposed systems are applicable today. The most convenient method is the combination of chemical row treatment and mechanical weeding between rows. It reduces the amount of herbicides by almost 70% with no negative effects on yields (Kemmer, 1988; Irla, 1989; Bin, 1989; Stemann & Lütke-Entrup, 1991). The costs of mechanical weeding and row treatments are not competitive with the cheap Atrazin alone but if combinations of several herbicides are applied because of resistant weeds, chemical weeding may be more expensive. The combination of hoeing and row treatment often is cost-effective in Switzerland at acreages above 10 ha (Irla, 1989).

Prevention of soil destruction and water pollution is best accomplished by green or dead plant covers. A multitude of cover crops and tillage systems have been developed recently which probably will be adopted by most farmers (Sturny & Meerstetter, 1990; Ammon et al., 1990; Raimbault et al., 1990; Estler, 1990; Winstel, 1991).

Table 10. Weed density, yield and costs of different weeding methods in winter wheat (cv. Arina) from 1988-90 in Switzerland (after Irla & Ammon, 1991)

Weeding method	Weed density (dry matter in kg/ha)				Yield (in kg/ha)				Costs SFr./ha*
	1988	1989	1990	1988-90	1988	1989	1990	1988-90	
Herbicide	60	-	180	80	7840	6790	6790	7200	60-240.-**
Herbicide ½ dosage	-	120	180	100	7850	6780	6790	7140	45-140.-**
Hoeing	230	110	560	300	7110	6900	6720	6910	120.-
Hoeing + currying	-	20	80	30	7290	6970	6820	7027	150.-
Hoeing,currying + herbicide ½ dosage	-	20	80	30	8110	7020	6960	7363	195-390.-**
Untreated	1010	750	1180	980	7000	6240	5740	6327	0

*) costs calculated for one intervention per season including labour, machinery costs, herbicide
**) variable costs of herbicides according to weed populations

Integrated cereal cropping systems

Until now we have considered mainly single protection methods and their effects on specific pests, diseases or weeds. Evidently, the farmer deals with complex cropping systems in which he has to integrate crop protection. In Integrated Farming Systems (IFS) and Organic Farming (OF), all crops on the farm are considered as being dependent on each other and its success is judged on the farm level. However, the economic results of cereal crops of integrated compared to conventional systems have been evaluated on experimental farms in several countries. Data from farms in Germany, The Netherlands and Switzerland demonstrate that optimally combined cultural and chemical control methods result generally in a reduction of pests, diseases and weeds (Kuhlmann & Heitefuss, 1987; El Titi & Richter, 1987; El Titi, 1990; Vereijken, 1990; Häni, 1990). Reduction of 60-80% in pesticide use in wheat in integrated farming systems (Table 11) show a yield reduction of 5-8% (Vereijken, 1989; Häni, 1990). Similar results are reported by El Titi (1990) from the "Lautenbacher Hof" in southern Germany. There, the average input of pesticides in wheat was reduced by approximately 40% in integrated systems, resulting in a yield loss of 8-10% in comparison to conventional farming. Consequently during 1980-86, pesticide costs in integrated winter wheat varied from 35-50% on average compared to conventional wheat (El Titi, 1990). In Switzerland, a decrease of pesticide costs of 70% was achieved.

Table 11. Use of pesticides and crop yields averaged per season in conventional (C) and integrated (I) winter wheat growing systems on experimental farms in The Netherlands and in Switzerland (data from Vereijken, 1989 and Häni, 1990)

	The Netherlands (Nagele 1984-87)				Switzerland (average of 3 farms 1987-88)	
	# Treatments per field		Active ingredient input (kg/ha)		# Treatments per field	
	C	I	C	I	C	I
Herbicides	2.2	0.6	4.9	1	1.3	0.6
Fungicides	2.2	1.3	1.3	1.1	2	0.3
Insecticides	0.8	0.5	0.13	0.1	0.9	0
Growth regulators	0.8	0	0.5	0	0.9	0
Total input	6	2.4	6.8	2.2	5.1	0.9
Crop yield (kg/ha)	7600	7000			6200	5700

Integrated farming is appealing to the farmer only if it is economically acceptable. This has been investigated in Germany, The Netherlands, and Switzerland. Some results with winter wheat are summarized in Table 12. The investigations were not carried out during exactly the same but at similar periods. For a good comparison, all financial results are converted into Swiss francs (SFr.). The absolute data vary considerably between the countries because of different prices of the product and the costs. For that reason, the differences between integrated and conventional systems are also indicated in relative figures. Crop yields in integrated systems are 4.7-7.9% lower. This reduction is translated into the total financial returns except if the grains could be sold at a higher price. The average allocated costs are reduced in the integrated systems with approximately 20% in all three countries. The gross margin of the integrated system is slightly positive on the Lautenbacher farm, but slightly negative at Nagele and in Switzerland. The table is not giving the final financial result because two main data, namely labour input and additional costs for machinery, are not included. Only in Lautenbach it was estimated that labour requirements in the integrated system is 16.7% lower than in conventional regime.

In conclusion, the results of integrated compared to conventional winter wheat cropping systems illustrate a substantial reduction in the use of pesticides and nitrogen fertilizer and about equal financial results. This should motivate all parties involved in cereal production to promote and to use cropping systems with low input of pesticides and fertilizer. This may become even more interesting when grain prices will decrease and costs will increase as can be expected in the coming years.

Table 12. Economic results of conventional (C) and integrated (I) wheat cropping systems in Germany, The Netherlands and Switzerland (data from El Titi, 1990; Vereijken, 1990 and Häni 1990)

	Germany (Lautenbacher Hof 1984-88)		The Netherlands (Nagele 1984-87*)		Switzerland (average of 3 pilot farms 1986-89)	
	C	I	C	I	C	I
Crop yield *(kg/ha)*	6500	6000 *- 7.7%*	7600	7000 *- 7.9%*	6390	6090 *- 4.7%*
Total returns *(SFr./ha)*[1]	2700	2485 *- 8%*	2784	2568 *- 7.8%*	6607	6295 *- 4.7%*
Allocated costs[2] *(SFr./ha)*	1207	961 *- 20.4%*	696	522 *- 20.7%*	1249	1012 *- 19%*
Gross margin[3] *(SFr./ha)*	1493	1524 *+ 2%*	2088	2016 *- 3.4%*	5358	5283 *- 1.4%*
Labour requirement *(h/ha/year)*	7.8	6.5 *- 16.7%*				

*) financial calculations based on prices 1987

[1]) exchange rates August 1991: SFr. 1.- = DM 1.15; SFr. 1.- = Dfl. 1.25

[2]) costs of fertilizers, pesticides, seed, insurance, variable machinery costs, interest

[3]) total returns - allocated costs

Conclusions and recommendations

Over the last 15 years there has been a substantial increase in intensity of cereal production in western Europe. Cultivating new, high yielding varieties and increasing inputs of N-fertilizer, pesticides and plant growth regulators led to high and stable yields. As a result, a yearly surplus of cereals are produced in EC and EFTA, prices are decreasing and governments are subsidizing sales on international markets. The farmer tries to compensate the falling prices with higher yields, lower costs and simplified cropping systems. As a consequence, in many countries society is confronted with tremendous costs to subsidize surplus production, and to combat environmental pollution and a depopulation of poorer parts of agricultural areas. In order to break this vicious circle some technical and political measures are proposed.

Technical measures and registration procedures

1. Resistance properties of cultivars should be given more attention in registration procedures.
2. Variety testing with use of fungicides and insecticides is considered inappropriate (except for detecting tolerant varieties). Susceptible varieties should be withdrawn.
3. Mixtures of varieties and multiline production should be promoted to prevent or delay breakdown of resistance.
4. Seed production of cultivar and line mixtures should be restructured to obtain ample seed supply

of mixtures.

5. Variety specific recommendations with respect to fungicide, insecticide and growth regulators are needed in order to optimize their use.
6. New pesticides should be approved only if environmental risks are lower than those registered previously.
7. Quick registration of environmentally safe products e.g. biological agents.
8. Mechanical weed control should be promoted as an acceptable alternative to herbicides. Combinations of mechanical weeding and reduced herbicide doses should be recommended, especially in maize.
9. Substantial reduction of pesticide use can be achieved by decision-support systems. Farmers should be strongly encouraged to use EPIPRE and similar systems.
10. Excessive doses of nitrogen fertilizer must be avoided and appropriate rates based on fast analytical methods like N-min should become common practice.

Political measures

1. Extra taxes on nitrogen fertilizer and pesticides should be introduced to discourage their use.
2. Ecologically produced grains should be subsidized to compensate the farmer for his ecological contribution to the society.
3. Environmentally safe methods, like biological control, should be supported by subsidies as it is done for *Trichogramma* in Germany.
4. More active support of a price policy favouring low input cropping systems. Their potential to reduce Europe's cereal surplus should be considered more carefully and the economic and ecological consequences should be studied.

Research and extension

Much research has been devoted to the development of integrated pest management in cereals. Many practical solutions ready to be applied have been offered but few have been accepted by the farmers. Why? All results in research are useless if extension services are incapable to translate them for practice. Extension services, specialized in plant protection, should play a key role in implementation of integrated pest management. However, they do not have enough manpower, so they cannot take care sufficiently of informing and guiding the farmers. Implementation of research through extension has to be promoted and carried out on special pilot farms.

Integrated plant protection and non-chemical control methods have reached a certain level but must be extended rapidly. Fast progress in integrated pest management in cereals will be achieved only if governments direct their political intentions into action.

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The biological control of soil-borne pests and diseases

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Summary

Soil-borne pests and diseases are inherently difficult to control and integrated strategies using several control methods have been used traditionally for their management. Chemical treatments are applied to some high value crops but reports of health and environmental hazards associated with their intensive use has caused further restrictions in their application. Some commercial companies have identified soil-borne pests and diseases as promising targets for biological control because chemical treatments are either unsuitable or inefficient. At present, no biological agent is used on arable crops because none has provided adequate or consistent levels of control. Interactions between the introduced organism and the soil environment are poorly understood. Natural control of some diseases such as Take-all and of some pests such as cereal cyst-nematode has been widely reported. Detailed studies of these naturally suppressive soils should provide valuable information on factors that affect biological contról in soil. The successful development of biological control agents is likely to depend on a thorough understanding of the biology and ecology of the pests and disease causing organisms and their natural enemies.

Introduction

In this paper I will concentrate on the biological control of nematode pests and soil-borne diseases attacking arable crops, but many of the comments will be relevant to the use of fungal agents for insect control. In general, the control of soil-borne pests and diseases is difficult and has relied on the use of crop rotation, resistant cultivars, green manuring, intercropping and chemicals, including the use of fumigants. Although the large costs (approx. \$400/ha) of broadcast and fumigant chemical treatments have resulted in their limited use on broad-acre crops, health hazards and environmental problems, including the contamination of ground water have been widely reported. As a consequence, a number of products, particularly nematicides, have been withdrawn from the market (Thomason, 1987), and several countries have legislated for a major reduction in the use of soil-applied pesticides.

Industry, currently spends approximately \$10 million per annum on all aspects of research on biological control (Powell *et al.*, 1990), and some companies have identified soil-borne pests and diseases as promising targets because chemical treatments are either inefficient or unsuitable. Although the research effort on biological control in non-commercial organisations is probably an order of magnitude greater than that in industry, it is still small compared to the investment made in the development of new chemical treatments or resistant cultivars. Currently, no biological control agents (BCA's) are being used in integrated control programmes for any soil-borne pest or disease of arable crops. Despite several significant exceptions BCA's have not yet provided adequate or consistent levels of control and there is a need for more research and development of carefully selected BCA's. Most biological agents have been developed for the control of insects attacking the aerial parts of crops and the market is dominated by the bacterial agent, *Bacillus thuringiensis*; <2% of products concern the control of plant diseases. This paper aims to highlight progress made in the biological control of soil-borne pests and diseases, outline the major research and development difficulties and assess the potential of selected BCA's in integrated pest management systems on arable crops.

Before addressing these issues it is appropriate to sound a note of caution in the development of integrated management strategies. Potato cyst nematodes, *Globodera rostochiensis* and *G. pallida*, are probably the most intensively studied nematode pests in the world and most European countries have research programmes aimed at their control. In the UK alone these pests cost growers approximately $85 million per annum and about $14 million are spent on chemicals for their control. As long ago as the late 1960's, a cultivar (Maris Piper) with resistance only to *G. rostochiensis* was introduced and, combined with the use of crop rotation and nematicides, an effective system for integrated control was applied. However, both research workers and advisors recommended that growers should not plant Maris Piper too frequently and that it should be alternated with susceptible cultivars because of its lack of resistance to *G. pallida*. This advice was largely ignored because of the large market which rapidly developed for Maris Piper and as a consequence *G. pallida*, which was relatively uncommon in the late 1960's in the major ware potato growing regions, is now common throughout UK ware potato areas. This nematode is more difficult to control with chemicals and the resistant cultivars currently available have only partial resistance (Whitehead, 1991). As a consequence, despite much research, there may now be a worse problem with potato cyst nematodes than there was 25 years ago; currently, some farmers apply a fumigant in the autumn and a granular nematicide in the spring to control these pests. Clearly, integrated pest management requires farmer acceptance and must have an educational component if it is to be successful.

The soil environment

Although some insect pests may be attacked by parasites and predators in the surface layers of soil (Edwards, 1976), most biological control of soil pests and diseases concerns the use of microbial agents. These agents are much affected by the soil environment and it is unlikely that they will be used successfully unless their ecology is understood (Deacon, 1991). Soil organisms are buffered from the extremes of the aerial environment but several key factors influence the activity and application of BCA's (Table 1). In all but the surface layers of soil, fluctuations in temperature and relative humidity are much smaller than above ground. Although moisture rarely limits the growth of fungi in soil, free water is necessary for the movement of zoospores and the activity of these spores is much affected by rainfall. Also, in temperate climates soil temperatures rarely reach 25^{0}C and it is important that laboratory and glasshouse tests are done at realistic temperatures. Soil acts as an effective buffer to environmental extremes because of its great bulk. However, the bulk of soil, estimated at 2,500 t/ha to plough depth, makes the control of pests and diseases difficult; chemical control of pests and diseases distributed throughout the soil usually involves the application of relatively high rates of mobile compounds if treatments are to be effective. Similarly, with BCA's the organism must be capable of spreading rapidly in soil or applications of inoculum would be too large and expensive. In-row applications and seed treatments may provide useful techniques for reducing application rates; for protection against pests and diseases attacking roots the BCA would need to spread and colonise the rhizosphere. The residual soil microflora may compete with the BCA for scarce nutrients and significantly reduce its survival and spread. Fungal BCA's introduced in soil on a pre-colonised energy base have established more readily in soil than when spores or hyphae have been added alone. Competition and antagonism from the soil microflora varies between soils and environmental conditions and can lead to variation in the efficacy of a BCA. The ability of the crop to withstand pest and disease attack and to support their multiplication will greatly influence the performance of the BCA; the impact of the plant is often ignored in the development of BCA's.

Types of microbial agents

Most work on the biological control of soil pests has concerned the use of parasites, in particular fungi. As bacteria such as *B. thuringiensis* and *B. popilliae* must be ingested to infect insects, they are unlikely to be effective for control of most soil insects. Entomophilic nematodes such as *Steinernema bibionis* search out their insect hosts in soil and have proved effective in controlling pests such as vine weevils attacking protected or container grown crops. These nematodes have broad host ranges and are widely distributed in soils; the risk to non-target organisms is unknown and must be assessed before entomophilic nematodes are released in large numbers as BCA's for pests on field grown crops. At present, the costs of production would preclude the use of nematodes in these situations. Parasitic fungi and some nematodes have, however, shown potential (Table 2.). Most reports of the biological control of plant-parasitic nematodes have concerned the use of fungi and bacteria (Kerry, 1987). Recently, there has been some evidence that rhizosphere bacteria may produce toxins or modify root exudates, resulting in significant reductions in the invasion of nematodes into plant roots. Also, mycorrhiza-colonised roots may be less attractive to some nematodes and reduce their multiplication.

Although mycoparasitism plays an important role in the control of soil-borne fungal diseases, competition and antagonism from other soil fungi or bacteria appear to be the major modes of action for many potential BCA's. Competition in the rhizosphere for essential nutrients such as C, N or Fe, antagonisms resulting from the production of toxins and antibiotics, and the induction of resistance have all been cited as important factors in preventing disease development. However, much of this information has been collected in laboratory conditions and the significance of these types of interaction in the field is frequently open to question (Deacon, 1991).

Table 1. Soil factors likely to influence the performance of microbial BCA's

Factors	Influence on BCA's
Temperature	- fluctuations much smaller than above ground; in temperate climates soil temperatures rarely exceed 15-18°C at 10 cm depth.
Moisture	- rarely below 99% RH even at pF 4.2 (PWP); water movement in soil important for dispersal of spores.
Structure/Texture	- major influence on colonisation and spread of BCA's; 2,500 t/ha of soil makes most broadcast treatments uneconomic. Protection from UV light.
Residual soil microflora	- competition with BCA's; fungistasis causing variation in efficacy of agent.
Host plant	- impact of host plant often crucial in determining efficacy of BCA's but frequently overlooked.

Types of biological control

Soils which suppress the multiplication of nematodes (Kerry, 1987) and the development of some fungal diseases (see Hornby, 1990) have been reported throughout the world and are frequently exploited by growers. Research on suppressive soils has led to the identification of the causal agents with potential as BCA's and has provided important information on the types of interactions that occur and the key factors that affect these relationships. Thus, studies of suppressive soils have greatly increased our ecological understanding which is essential for the successful deployment of BCA's. Suppressive soils are slow to establish and it has proved difficult to manipulate this natural control with treatments that are practical for a grower. However, it is important to ensure that the use of chemicals and agronomic practices do not destroy the natural control agents present in suppressive soils and allow pests and diseases to increase.

The induction of biological control by the application of selected organisms relies on the existence or creation of a suitable niche for the agent to occupy in soil to the detriment of specific pests or diseases. The activity of the agent is affected by environmental conditions and by the method of its production, formulation and application. These interactions may be complex and are often poorly understood. Experience to date indicates that the use of BCA's in arable crops will be difficult and require integration with other control methods; there is no evidence that biological control alone will replace the use of chemicals. However, combined with treatments such as: a) crop rotation and soil amendments to manipulate the amount of pathogen inoculum present and increase the activity of agents, or b) using partial soil sterilisation by, for example, solarisation, to reduce the soil microflora and help establish applied BCA's in soil, may lead to effective methods of soil-borne pest and disease management. Biological control agents may be more effective in composts and other semi sterile growing media in which competition from the residual microflora is low; particular success may be achieved with container grown plants for which inundative treatments may be applied. Although most pests and diseases in such growing media can be controlled by suitable hygiene procedures, it is apparent that some pests such as the black vine weevil *Otiorhynchus sulcatus*, and some root diseases can be problems that require treatment.

Table 2. Some microorganisms associated with the biological control of soil insects, nematodes and fungi

Pest/disease	Agent	
Insects	Parasites	: *Beauvaria bassiana*, *Metarhizium anisopliae* *Bacillus popilliae*, *Steinernema* spp.
Nematodes	Parasites	: *Nematophthora gynophila*, *Verticillium chlamydosporium*, *Pasteuria penetrans*
	Competitors/ antagonists	: rhizosphere bacteria, mycorrhizal fungi
Fungi	Parasites	: *Pythium oligandrum*, *Trichoderma* spp. *Gliocladium virens*
	Competitors/ antagonists	: *Fusarium oxysporum*, *Phialophora graminicola* fluorescent pseudomonads

Examples of biological control systems

Two agents, *Phlebia (Peniophora) gigantea* for the control of *Heterobasidion annosum* on tree stumps and *Agrobacterium radiobacter* which is applied as a root dip for control of crown gall caused by *A. tumefasciens*, are used commercially with considerable success. In both situations the agent is applied as an inundative treatment to a specific and readily accessible niche, and has a short-term effect with a long-term benefit (see Deacon, 1991). The use of BCA's for control of most soil-borne pests and diseases is more complex and selected problems are discussed below.

Suppressive soils

Take-all caused by the fungus, *Gaeumannomyces graminis* var. *tritici*, is a major disease that attacks the roots, crown and stem base of wheat and barley and has a worldwide distribution. Resistance in plants has not been found and fungicides are not effective so that control of this disease depends on crop rotation. However, in monocultures of susceptible cereals Take-all may decline after the third crop and be effectively controlled thereafter. The decline is caused by the build up of microorganisms antagonistic to *G. graminis* var. *tritici* which inhibit the build up of disease in roots. A wide range of organisms, including fungi, bacteria, viruses and amoebae, and of mechanisms, including antibiosis, competition for Fe and by avirulent strains of *G. graminis*, have been associated with Take-all decline (TAD). However, TAD appears to be complex and is unlikely to be caused by a single agent. Attempts to control Take-all by applications of fluorescent pseudomonads have resulted in significant yield increases but often the effect has been variable and insignificant.

In general, the development of TAD has been associated with fertile soils in which the intensive cropping of cereals has been facilitated by high inputs of fertilisers and crop protection chemicals, particularly fungicides and herbicides, to support high yields. Such cropping systems are common in Europe where soils tend to have relatively high levels of organic matter and be microbiologically very active; it has proved difficult to establish BCA's for Take-all in these conditions. However, in less fertile soils such as those in Australia and Western USA where wheat yields are <3 t/ha, BCA's may have large effects but TAD differs in its development from the 'classical' form or has not been recorded (Hornby, 1991). Such trends derived from long term data sets and reviews of the literature may help in targetting the use of BCA's and the development of management systems.

It has been clearly demonstrated that soils may become suppressive to some plant-parasitic nematodes (Kerry, 1987) in a similar way to the development of TAD. Some detailed studies on such natural control have concerned the cereal cyst nematode *Heterodera avenae* which fails to multiply on the roots of susceptible cereals when these are grown in monocultures. During the first 3-5 years of monoculture the nematode multiplies and causes much damage before suppression is induced. Thereafter, the nematode is controlled at levels below the economic threshold. Two fungi, *Nematophthora gynophila* and *Verticillium chlamydosporium*, which parasitise adult female nematodes and their eggs, have been identified as the causal agents in many soils throughout N. Europe. Their effects have been quantified in suppressive soils where >95% of the females and eggs were parasitised (Kerry *et al.*, 1982). Soils that suppress other nematodes have been reported but it is not clear whether the nematophagous fungi and bacteria cited as causal agents are responsible for the control observed; in all cases suppression has developed in monocultures or in perennial crops where a long association between pest nematodes and their natural enemies can establish. There is a need for quantitative studies on these suppressive soils.

The natural enemies in nematode-suppressive soils might, a) enable growers to shorten rotations on nematode-infested soil, b) prolong the useful life of resistant cultivars by parasitising virulent female nematodes and, c) enhance the long-term effectiveness of nematicides or enable dose rates to be reduced. Before growers can exploit these opportunities there is a need to develop methods to identify suppressive soils and to predict the expression of suppression.

Biological control agents

Damping-off diseases of seedlings caused by *Pythium* spp., *Fusarium* spp. and *Rhizoctonia solani* may kill plants before or soon after their emergence by causing rots in the roots or at the base of the stem. These diseases can be controlled by treating seed with fungicides and by cultural methods which reduce the amount of fungal inoculum in soil and ensure the rapid growth of the seedling. As protection is required for a relatively short period (established plants are much less susceptible) and for a limited extent of plant tissue, damping-off diseases were considered suitable targets for BCA's. However, despite much research selected BCA's have a) not provided broad spectrum control of the different causal fungi, b) not spread sufficiently to prevent the development of disease post-emergence and c) not proved as consistent or predictable as fungicides. Some seed treatments have been produced commercially and are based on *Trichoderma* spp. This fungus is a soil saprophyte and is a relatively weak coloniser of plant tissues; it has been estimated that 5 x 10^4 propagules of *Trichoderma* are required for each propagule of *R. solani* at the densities at which this pathogen normally occurs in soil (Adams, 1990). Antagonists isolated from the plant tissue which they will be required to protect or from the organism they will be used to parasitise might be more effective BCA's capable of providing long-term, consistent biological control. Clearly, the protection of the root systems of arable crops throughout a growing season is a formidable task for a BCA at practical rates of soil inoculation.

Verticillium chlamydosporium has been isolated from the eggs of several species of cyst and root-knot nematodes in soils throughout the world (Kerry, 1988). It is a facultative parasite capable of colonising the rhizoplane of a range of crops. One isolate of the fungus has been selected as a BCA for root-knot nematodes and its epidemiology studied. The relationship between nematode population density, fungal application rate and nematode control have been investigated in the glasshouse; approximately 5 x 10^3 chlamydospores/g soil of the fungus are required to control the nematode. The fungus can be introduced in soil without an energy base, colonise the rhizoplane and survive throughout a growing season in soils at 20-30°C, but nematode control is greatest at 25°C (de Leij & Kerry, 1990). The fungus can be readily grown on a range of solid and liquid media but improved methods of production and formulation are needed for testing in the field. The fungus does not penetrate the root cortex and so egg-masses of the nematode produced within large galls are not exposed to infection. Hence, when good hosts for the nematode such as tomato plants are grown in heavily infested soil, *V. chlamydosporium* does not provide adequate control. However, the fungus may be useful as a prophylactic treatment to prevent the establishment of large nematode infestations; it remains to be seen whether *V. chlamydosporium* will be developed commercially.

Concluding comments

There is little doubt that natural enemies can provide long-term effective control in situations where some pests and diseases might normally be expected to cause significant yield losses. To a certain extent this natural control, which has often developed fortuitously, can be manipulated to the benefit of the grower. However, the exploitation of BCA's has had very limited success to date and it remains to be seen whether methods of production, formulation and application can be developed sufficiently cheaply to enable these agents to be used on arable crops. What is clear, however, is that success will depend on a) the careful selection of suitable agents, b) a thorough understanding of the ecology of the agent and the pest or disease target, c) the integration of biological with other methods of management and d) close collaboration between research workers and industry. With much public concern about environmental problems associated with intensive agricultural production the climate has rarely been as bright for biological control methods but much basic research is required on most potential BCA's before their future role in the management of soil-borne pests and diseases can be adequately assessed.

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Region-wise development of prototypes of integrated arable farming and outdoor horticulture

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Summary

In The Netherlands integrated arable farming systems (IFS) are developed at three regional experimental farms, with region-specific crop rotations and cropping systems. Most pesticide and fertilizer inputs appear to be replacable by non-chemical methods and organic manure, with economic results similar to conventional systems. The targeted reductions in pesticide use in The Netherlands' Crop Protection Policy Plan for the year 2000 can already clearly be met. Further improvements of the prototype systems are considered. Recently started farming systems research for outdoor horticulture is briefly discussed.

Introduction

In The Netherlands, prototypes of integrated arable farming systems (IFS) are developed region-wise at three experimental farms. They are located at Nagele (since '79) in the central clay area, at Borgerswold (since '86) in the northeastern sand area and at Vredepeel (since '89) in the southeastern sand area, representing the major soil types in arable farming.

The IFS strategy is described by Vereijken (1992) and is shared by an international working group on IFS in the International Organization of Biological and Integrated Control (IOBC/WPRS) (Vereijken & Royle, 1989).

For the situation in The Netherlands this general IFS strategy has been elaborated as consistent substrategies of crop protection (Vereijken, 1989a), fertilization (Vereijken, 1990) and of cropping systems of wheat (Vereijken, 1989b), potato (Vereijken & van Loon, 1991) and sugar beet (Wijnands & Vereijken, 1989). These substrategies were recently assembled in a handbook of IFS for practice, extension and education (Vereijken & Wijnands, 1990).

The IFS-strategy in The Netherlands aims at reduction of high inputs of pesticides and nutrients which are seriously affecting the quality of the biotic and abiotic environment. The government in The Netherlands recently accepted two policy plans to restructure and sanitize the national agriculture (Anon., 1990; Anon., 1991). The following points are most relevant for arable farming and outdoor horticulture.

- Concerning pesticides the inputs of active ingredients must be strongly reduced (50% in 2000 compared to 1985-1988) and the spectrum of registered pesticides will be drastically sanitated (no mobile and persistent pesticides).
- Concerning nutrients the volatilization of ammonia must be strongly reduced (70% in 2000 compared to 1985) as well as N- and P-emissions into the Northsea (70% in 2000 compared to 1985). Besides, quality criteria for N and P in surface-(2.2 mg N/l and 0,15 mg P/l) and groundwater (11.2 mg N-NO_3^-/l) have been set. The use of organic manure is restricted in

dosage (P-norm), timing and application techniques. Measures including criteria of soil mineral N in autumn are under discussion in order to restrict NO_3-leaching to the groundwater.

Consequently, agriculture in The Netherlands must adopt the quality of the environment as a major objective and integrate it with the conventional objectives of income and employment. The government considers such integrated farming systems as the best way to achieve a competitive, sustainable and safe agriculture. In 1994, at least 30% and by 2000 100% of the farmers should practise integrated farming, according to the policy plans (Anon., 1990). Therefore a project has been set up to introduce integrated farming into practice on an experimental basis, as described by Wijnands (1992). In the present article the regional development of IFS prototypes on experimental farms is described as a preceding step.

Regional development of IFS-prototypes

Central clay area (Nagele)

The most important arable production areas in The Netherlands are the southwestern, central- and northern clay area. Most of these soils are well drained and very fertile. The small farm size (25-50 ha) urges farmers to grow financially high yielding crops in short rotations with high inputs. Potato is the most profitable crop, followed by sugar beet and vegetables such as onion and cabbage. Cereals are financially less attractive but are needed as break crops. Most rotations consist of only three or four years. Consequently, beet and potato cyst nematodes cause serious problems, forcing farmers to regular soil fumigation as a curative or preventive measure. In the central clay area ware potato and in the northern clay area seed potato are the most important crops. In the southwestern area rotations are traditionally more diversified by crops as flax and poppies.

Besides the general IFS aims, an IFS prototype for the clay soils aims at non-chemical control of potato cyst nematodes. A potato cropping frequency of 1:4 is considered as a good balance between sound rotations with lower profits (1:5 or 1:6) and financially high yielding short rotations under pressure of pest and diseases (1:3) and therefore requiring high pesticide inputs.

The IFS-prototype for clay soils is developed since 1979 at the national experimental farm for the development and comparison of alternative farming systems, set up under the name "Development of Farming Systems" (DFS) at Nagele (North-East Polder). The size of the farm is 72 ha and the soil is heavy sandy marine clay (24 % lutum). Three farming systems have been studied until 1991: integrated, conventional, and organic (biodynamic) (Table 1). More details on this project can be found in Zadoks (1989), Vereijken (1989c), Wijnands (1990) and Hofmeester & Wijnands (1990). The IFS prototype does not differ from conventional systems in cropping frequency of the major crops or cropping plan (Table 1) and is characterized by:

- non-chemical strategy to control nematodes, through consistent volunteer control and the use of resistant cultivars based on intensive monitoring of the pathotype and population density of potato cyst nematode infestations (Schomaker & Been, 1990);
- reduced fungicide input through the use of resistant and tolerant cultivars, moderate fertilization levels, etc. (Integrated crop protection; Vereijken, 1989a). For instance potato cultivars are grown, which are less susceptible to potato blight (*Phytophthora infestans*). However, on the Dutch cultivar list with approximately 100 recommended cultivars, it is hard to find profitable alternatives for the most common cultivar Bintje which is highly susceptible to potato blight and nematodes and therefore strongly depends on high pesticide inputs (Vereijken & van Loon, 1991). So there is an urgent need for new cultivars combining a

broad resistance with a good quality for processing and consumption;

- mechanical weed control mainly based on hoeing techniques with additional band spraying of herbicides, if necessary;
- reduced N input and PK input/output balances on the farm level, based on environmentally safe and agronomically efficient use of organic manure according to a strategy of integrated nutrient management (INM; Vereijken, 1990).

Table 1. Farming systems and crop rotations at the three experimental farms in The Netherlands (Nagele, Borgerswold and Vredepeel)

Nagele	**Conventional(reference)/Integrated**		**Biodynamic**
	1. ½ ware-, ½ seed potato		1. ware potato
	2. ½ dry pea, ¼ carrot, ¼ onion		2. winter wheat
	3. sugar beet		3. winter carrot
	4. winter wheat		4./5./6. 3-year grass/clover
			7. onion
			8. winter wheat/seed potato
			9./10./11. 3-year grass/clover
Borgerswold	**Conventional(reference)**	**Conventional/Integrated(less root crops)**	
	1. starch potato	1. starch potato	5. starch potato
	2. sugar beet	2. spring wheat	6. field bean
	3. starch potato	3. dry pea	7. sugar beet
	4. winter wheat	4. grass seed	8. winter wheat
Vredepeel	**Integrated (more root crops)**	**Conventional/Integrated (reference)**	**Integrated (less root crops)**
	1. ware potato	1. ware potato	1. ware potato
	2. sugar beet	2. sugar beet	2. sugar beet
	3. winter wheat	3. winter wheat	3. winter wheat
	4. scorzonera	4. scorzonera	4. scorzonera
	5. ware potato	5. ware potato	5. ware potato
	6. sugar beet	6. sugar beet	6. maize
	7. carrot	7. maize	7. pea
	8. pea/dwarf bean	8. pea/dwarf bean	8. grass seed

Northeastern sand area (Borgerswold)

Farms in the northeastern sand area are generally small (20-40 ha) with sandy soils or reclaimed peat soils where organic matter contents vary between 3 and 20% and weed pressure is extremely high. The area strongly depends on the growing and processing of starch potato with an average cropping plan of 50% starch potato, 25% sugar beet and 25% cereals and other crops. The gross margin of sugar beet is the highest, followed by starch potato. All other arable crops are far less profitable. Notwithstanding the intensive use of nematicides and the use of potato cyst nematode resistant cultivars, potato cyst nematodes have heavily infested the total area (*Globodera rostochiensis; RO_1, RO_2, RO_3* and *RO_5; Globodera pallida; PA_2 and PA_3*). Root-knot nematodes (*Meloïdogyne hapla*) are of increasing importance, since cereals as the only non-host crop are more and more substituted by pulses and vegetables. The high proportion of root crops makes soil fertility and -stability decrease, because of insufficient input of organic matter and intensive soil cultivation. As a result, there are serious problems with wind erosion, especially in dry periods on fallow land. The prices of starch potatoes are under pressure since they are indirectly coupled with the EC-cereal prices.

Cropping costs are high, especially those of soil fumigation. So the area has gloomy perspectives and as a consequence farmers tend to set-aside. Moreover, the use of nematicides and fungicides will be restricted by law in the immediate future.

In this region, the IFS approach aims at non-chemical control of nematodes and restoration of soil fertility. It requires a more diversified crop rotation and less frequent cropping of potato (from 1:2 to 1:4) by increasing the proportion of monocotyledonous crops in the cropping plan (Table 1). The development of an IFS prototype for this region started in 1986 at the experimental farm Borgerswold. On this 34 ha farm three systems are laid out: a conventional (reference) system, a diversified integrated system and a similar but conventionally managed system to enable differentiation between the effects of a more diversified crop rotation and integrated management (Table 1).

The IFS prototype for the sand and peat district is characterized by:

- a sound and diversified crop rotation aimed at restoration of soil fertility in physical, chemical and biological (including soilborne pest and pathogens) terms;
- non-chemical control of potato cyst nematodes based on a maximum cropping frequency of 1:4, the choice of cultivars with maximum resistance and tolerance and detailed monitoring of population density and pathotype. Additionally it is aimed at an early harvest under good soil and weather conditions and a consistent volunteer control through the use of appropriate implements at harvest, non-inversion tillage before winter (freezing of tubers) and mechanical and chemical control in the following crop, if necessary. This strategy is completed by minimal turning tillage in subsequent crops to keep nematodes and fresh organic matter in the upper 10 cm soil layer where antagonistic activity is highest and cysts are most exposed to fluctuations of moisture and temperature. Soil life should be activated by maximum use of green- and organic manure and by minimum use of chemicals. As a result, the mortality rate of the nematodes is expected to increase as is confirmed by the preliminary results (Figure 1);
- mechanical weed control in so far it does not endanger soil stability. In a rotation with a good balance between mowed and lifted crops and minimum turning tillage these risks are limited. On these sandy soils harrowing is the basis for weed control in most crops completed by hoeing and the use of herbicides in band sprays, when necessary;
- reduced fungicide input by the use of resistant and tolerant cultivars, moderate fertilization levels, etc. (Integrated crop protection; Vereijken, 1989a). A reduction of fungicide input for the potato in addition to that caused by the decrease in potato cropping frequency is hard to realize, in spite of the considerable degree of resistance of the current cultivars. High disease pressure in the region provoked by high cropping intensity of potato and the poor volunteer control, is the major constraint. The use of reduced rates of fungicides with equal intervals between sprays as in the conventional system might further reduce fungicide inputs (Fry, 1978).
- reduced N input and PK input/output balances on the farm level, based on environmentally safe and agronomically efficient use of organic manure, as at Nagele.

Southeastern sand area (Vredepeel)

The southeastern sand area is characterized by a high degree of mixed plant and animal production. Most of the predominantly arable farms in this area are very small (10-30 ha) and grow financially high yielding crops in short rotations. Many farmers developed animal 'factory farming' units, based on high inputs of feed stuffs and maize monoculture for silage and for disposal of the animal manure. The volume of indoor animal production, particularly of pigs, increased exponentially over the last 20 years, resulting in a huge surplus of organic manure. As a result nutrient balances on the farms and in the region as a whole are seriously disrupted, which is the major cause of the disrupted national nutrient balance (Aarts & Biewinga, 1992). Dumping of manure is causing serious NH_3-volatilization and leaching of NO_3^-, K and even P, when the soil gets saturated. Arable farms, whether or not with a "factory farming" unit, mostly combine potato and sugar beet with vegetables for the canning industry. The proportion of graminea in the cropping plan is minimal because of their low profit. The lack of stable and sound crop rotations, combined with the high proportion of root crops in the cropping plan causes increasing problems with soilborne pests and diseases like root-knot nematodes and *Rhizoctonia solani*. This often affects quality of root vegetables like carrot and scorzonera eventually leading to price decline or even to crop failure. Since winter cereals are being substituted by spring sown crops, wind erosion and weed pressure are increasing. As a result, it is doubtful whether the farming activities are sustainable in both agronomical and economical sense.

Therefore IFS aims at a drastic sanitation of the disrupted nutrient balances, restoration of the soil stability and non-chemical control of soilborne pests and diseases. The latter should not endanger the quality of the vegetables, so a sound and diversified crop rotation is needed. The development of prototypes of IFS was started in 1989 at the experimental farm Vredepeel (near Venray). Considering the large variation in type and scala of activities various prototypes are being studied. For the smaller holdings the question is how intensive rotations (root-crop dominated) can remain if inputs are to be reduced while maintaining quantity and quality of the output. For the larger holdings the question is to what extent rotations can be extensified while maintaining sufficient economic profit. As a result, three integrated systems are studied with various ratios between mono- and dicotyledonous crops together with a conventional reference of the intermediate system (Table 1).

Features of this regional IFS approach are:

- consistent, root-crop dominated rotations aiming at restoration of soil fertility and non-chemical prevention/control of soilborne pests and pathogens;
- reduction of fungicide input by the use of resistant and tolerant cultivars, moderate fertilization levels, etc. The frequent irrigations, needed in dry summers, seriously hamper a reduction in fungicide-input for the potato crop. As in Borgerswold reduced rates of fungicides used at regular intervals may help to overcome this problem;
- mechanical weed control based on harrowing and hoeing completed with band spraying of herbicides;
- drastic sanitation of the nutrient balance by control of inputs of P and K, which implies a strongly reduced use of organic manure in comparison to the conventional system. Reduction of N input according to the integrated nutrient management strategy.

Preliminary results

The two main criteria to evaluate the perspectives of IFS are the economic feasability and the environmental impact. For the latter the input levels of fertilizers and pesticides are important indicators. The economic feasibility is indicated by gross margins, net surpluses and labour returns.

Pesticide inputs and costs

The total use of pesticides per year, expressed as kilograms active ingredients per ha (Table 2), is in the IFS prototypes reduced by 50-65%, excluding nematicides and even by 85-95% when nematicides are included, compared to the conventional reference systems.

Table 2. Annual input (kg/ha) of active ingredients of pesticides per system at the three experimental farms (I=integrated, C=conventional, R=reference, MR=more root crops, LR=less root crops, see Table 1)

	Nagele '86-'90		Borgerswold '86-'90				Vredepeel '89-'90		
	C_R	I	C_R	C_{LR}	I_{LR}	I_{MR}	C_R	I_R	I_{LR}
Herbicides	4.0	1.4	2.8	2.6	1.0	1.3	3.0	1.0	0.8
Fungicides	5.6	2.1	6.8	3.8	3.5	3.6	6.8	3.4	3.5
Insecticides	0.5	0.2	0.1	0.2	0.0	0.2	0.2	0.1	0.1
Growth reg.	0.3	0.1	-	-	-	-	0.0	-	-
Subtotal	10.4	3.8	9.7	6.6	4.5	5.1	10.0	4.5	4.4
Nematicides	29.7	-	71.4	38.0	-	-	22.3	-	-
Total	40.1	3.8	81.1	44.6	4.5	5.1	32.3	4.5	4.4

C_R =1:2 potato; regular soil fumigation; alternating low and highly resistant cultivars; normal soil cultivation.

I_{LR} =1:4 potato; no nematicide use; highly resistant cultivars; minimal turning tillage.

C_{LR} =1:4 potato; regular soil fumigation, alternating low and highly resistant cultivars, normal soil cultivation.

Despite the differences in location and rotation, the herbicide input in the integrated systems hardly differs (0.8-1.4 kg active ingredient/ha). This means a reduction of 60 to 75% compared to the conventional reference systems actieved by mechanical control and band spraying techniques. In all of the approximately 15 crops herbicide use is substantially reduced while mobile, toxic and persistent chemicals are avoided. At the clay location Nagele herbicide use can mostly fully be avoided in potato and winter wheat. At Borgerswold the input of herbicides is comparable in both conventional managed systems. In the integrated system, it is used 65% less. At Vredepeel the herbicide input is 57, 67 and 73% less in the three integrated systems, respectively the more root-crop dominated system, the reference system and the less root-crop dominated system. At the sand locations Borgerswold and Vredepeel herbicides mostly are fully substituted in potato, maize, field bean, winter wheat, spring wheat and certain species of grass for seed production. Consequently, allocated costs of weed control are Dfl. 150,- to 200,- less per hectare at Vredepeel and Nagele (contractors costs included, machine/fuel and own labour excluded).

Fungicide inputs are reduced with 50-65% depending on the location. At Nagele the fungicide use in potato is reduced by more than 60% by the use of resistant cultivars and a moderate nitrogen fertilization. The fungicide use in onion is also reduced by more than 60% by supervised control based on monitoring the time of initial infestation by *Botrytis squamosa* and weather conditions.
At Borgerswold the reduction of fungicide use is based on a 50% reduction in potato cropping frequency (Table 1). A further reduction is hampered by the very high pressure of potato blight in the region (Table 2). At Vredepeel the major part of fungicide reduction is achieved in scorzonera by using synthetic fungicides in a reduced frequency and the use of a cultivar more resistant to *Erysiphe cichoracearum*. The fungicide input in the three integrated systems is hardly different since the most fungicide demanding crops as potato and scorzonera are present in all three. Despite the use of more resistant potato cultivars, a reduction in fungicide input could not be achieved, because of the frequent irrigation of this crop during the last two dry summers.

Insecticides are minimally used on all locations due to low insect pressure and the use of control thresholds, reduced-dose techniques and band spraying. In all IFS systems the conventional use of huge amounts of soil fumigants against potato cyst nematodes is fully substituted by a combination of non-chemical measures, particularly resistant varieties. In the conventional system at Nagele, nematicides are preventively used to protect the common potato cultivar Bintje which is highly susceptible to potato cyst nematodes. In the conventional system at Borgerswold, soil is fumigated every second year after potato. At Vredepeel, soil is fumigated once in eight years to control all types of nematodes, but in particular to reduce the weed problem in scorzonera.

The total reduction in direct pesticide costs differs between the locations (Table 4). At Nagele the reduction is Dfl. 480.-/ha. At Borgerswold diversification of the cropping plan alone reduces costs by Dfl. 260.-/ha (C_{LR}). Additional integrated management brings a further cost reduction of approximately Dfl. 300.-/ha (I_{LR}). At Vredepeel the cost reduction ranges from Dfl. 150,-/ha for the most root-crop dominated system to Dfl. 240.-/ha for the reference system and the less root-crop dominated system.

Nutrient inputs and costs
The input levels of P and K in the integrated systems are considerably reduced according to the nutrient strategy of IFS (Vereijken, 1990) equalling more or less the average output from the farm (Table 3). On all three locations 100% of the P demand and 60-100% of the K demand in the integrated systems is covered by organic manure. The applied amounts of organic manure are also covering around 60-70% of the total N input.

At Nagele, the anorganic N input is reduced by 75 kg/ha compared with the conventional system. At Borgerswold, diversification of the crop rotation enables a reduction of 45 kg/ha and even 110 kg/ha in case of integrated management. For Vredepeel the anorganic N use is comparably low in all systems, since organic manure is traditionally the basis for the agriculture in the region. The high N, P and K input in the conventional system of Vredepeel reflects this. The total N input is respectively 65, 70 and even about 150 kg/ha lower for the integrated systems at Nagele, Borgerswold and Vredepeel compared to the conventional reference systems. For Borgerswold there is no difference in total N input between the conventional (C_{LR}) or integrated (I_{IR}) diversified systems. From an integrated point of view the high inputs in all conventional systems are considered as agronomically unnecessary and environmentally undesirable (accumulation of nutrients, increasing risk of leaching).

Detailed nutrient balance sheets of the systems at Nagele and NO_3^--concentration assessments of the drainwater (Vereijken, 1989c), show that the lower surplus of N on the balance of the integrated system (85 kg/ha versus 130 kg/ha in the conventional system over '86-'88) leads to less NO_3^--leaching (8 mg N-NO_3^-/l drainwater in the integrated system versus 10 mg N-NO_3^-/l in the conventional system).

Table 3: Annual input (kg/ha) of N, P and K per system at the three experimental farms (legends, see Table 2).

		Nagele '86-'90			Borgerswold '86-'90			Vredepeel '89-'90		
		C_R	I	C_R	C_{LR}	I_{LR}	I_{MR}	C_R	I_R	I_{LR}
N	anorganic	125	50	160	115	50	45	65	50	55
	organic	90	100	90	65	130	130	270	145	130
	total	215	150	250	180	180	175	335	195	185
P	mineral	10	0	10	15	0	0	5	0	0
	organic	35	30	30	20	35	30	60	35	30
	total	45	30	40	35	35	30	65	35	30
K	mineral	115	45	95	75	20	30	0	0	0
	organic	65	70	55	40	90	95	220	120	105
	total	210	115	150	115	110	125	220	120	105

The IFS fertilization strategy based on a decrease of total nutrient input and substitution of expensive mineral and anorganic nutrients by cheap organic nutrients, reduces costs by Dfl. 140.-; 190.-; 30.-/ha for Nagele, Borgerswold and Vredepeel, respectively (Table 4).

Economic feasibility

The Nagele results show that the net surplus of the integrated system equals that of the conventional system (Vereijken, 1989c). The average gross margin of the integrated system equals that of the conventional system (Table 4). For Borgerswold and Vredepeel a total economic evaluation still has to be made, so only gross margins are presented. The results of Borgerswold show that crop diversification causes a serious reduction in average gross margin. By utilizing the chances offered by a diversified rotation by an integrated management, the average gross margin can be improved.

The current difference in gross margin between the integrated (I_{LR}) and conventional reference system is caused by some problems at the start (not corrected for in the data presented) and the differences in cropping plan. If in the integrated system instead of once, sugar beets would be grown twice every 8 years the gross margin would only fall short Dfl. 100,- per hectare. If the results of '86-'90 for Borgerswold are recalculated based on current prices, the integrated prototype improves the gross margin by approximately Dfl. 100.- per ha compared to the conventional system. These examples illustrate the need of optimization by economic modelling studies before and after the experiments.

The preliminary results of Vredepeel show a small difference in average gross margin between the conventional and integrated reference systems. After the usual conversion problems in the first year, the second year already showed a better result for the integrated reference system. This system is expected to equal or even exceed the conventional reference system. The more root-crop dominated integrated system clearly exceeds the reference systems with some Dfl. 1000.- per ha, and the less root-crop dominated system falls some Dfl. 1000.- per ha short in average gross margin compared to the intermediate systems. These effects are mainly caused by the choice of carrots as financial high yielding crop. However, it is questionable whether the current rotation can maintain these yields.

Table 4. Annual costs (1000 Dfl/ha) of fertilization and crop protection, and average farm gross margin per system at the three experimental farms (legends, see Table 2).

	Nagele '86-'90			**Borgerswold '86-'90**			**Vredepeel '89-'90**		
	C_R	I	C_R	C_{LR}	I_{LR}	I_{MR}	C_R	$I_{R/}$	I_{LR}
Crop protect.	0.73	0.24	0.80	0.54	0.24	0.30	0.55	0.21	0.22
Fertilization	0.39	0.30	0.43	0.32	0.24	0.12	0.14	0.11	0.11
Gross margin	5.67	5.65	2.70	1.93	2.28	5.89	4.91	4.82	3.81

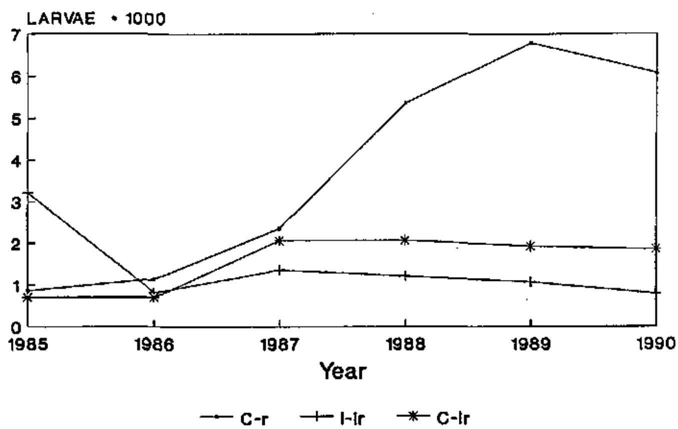

Figure 1. Occurrence of potato cyst nematodes in the three systems at Borgerswold 1986-1990 (average number of larvae/100 cc soil per field, samples 0-30 cm).

Figure 1 shows promising results of IFS for the control of potato cyst nematodes at Borgerswold. The conventional system keeps the highest infestation despite frequent soil fumigation, which demonstrates the failure of chemical control of potato cyst nematode in 1:2 rotations. The population levels are quite similar in the integrated and conventionally managed diversified systems. Obviously, soil fumigation can be substituted by the integrated control strategy for nematodes. Again, the question of sustainability of the IFS approach can only be answered on the longer term.

Perspectives and constraints

Following a regional problem analysis specific IFS prototypes are being developed, based on suitable crop rotations and appropriate cropping systems. The preliminary results demonstrate that pesticide and nutrient inputs can be substituted for the greater part by non-chemical methods with results comparable to conventional systems, after some optimization. The strong reduction in pesticide inputs clearly exceeds The Netherlands' policy aims for 2000 (Table 5). Although nutrient inputs were reduced and inorganic fertilizers were for a great deal replaced by organic fertilizers, it might not be sufficient to meet the norm-levels for $N\text{-}NO_3^-$ in groundwater at the two sand locations Borgerswold and Vredepeel. Therefore, additional research started in 1991. At Nagele (clay), leaching of N is reduced by 20% which is not considered as problematic in relation to the quality demands for surface- or groundwater.

Considering the changing agricultural policy in The Netherlands and the promising IFS results, the conventional system at Nagele is no longer relevant. As a result, it will be replaced by an advanced integrated system. This change provides the experimental freedom to develop new methods and techniques aimed at further reductions in pesticide and nutrients in- and output (emissions). The biodynamic mixed system is transformed into an arable/vegetable system which corresponds better with the system of the organic farmers in The Netherlands. The current integrated system will aim at maintaining the low pesticide and nutrient input, realized so far and at optimization of the economic results.

Tabel 5. Percentual reductions in pesticide use (kg active ingredient/ha) of the IFS prototypes at the three experimental farms and the targeted reductions of the crop protection policy plan (Anon, 1991).

	Nagele[1] '86-'90	Borgerswold[1] '86-'90	Vredepeel[1] '89-'90	Crop protection policy 1995	2000
Herbicides	65	64	67	30	45
Fungicides	62	49	50	15	25
Insecticides	60	99	50	15	25
Total[2]	63	54	55	20	33
Nematicides	100	100	100	50	70

[1]) Reduction in % for the I_R (Borgerswold I_{LR}) systems in comparison to the C_R system.

[2]) Total concerns all pesticides excluding nematicides.

At Borgerswold crop extensification (less root crops) alone while maintaining conventional management leads to serious income losses. In this respect standard economic calculations are right. However an IFS approach based on a less root-crop dominated rotation may almost bridge the economic gap with the conventional reference system. Also here the experimental design is adapted. The conventional system with less root crops is replaced by an IFS prototype aimed at maximum feasibility and optimum economic results. The cropping frequency of the major cash crop sugar beet is increased from 12.5% to 25% and the weed control strategy is adapted towards minimum labour and machinery costs. The use of pesticides will then of course be reduced to a lesser extent than in the current integrated system. The development of the latter will be continued. The prevention of nitrate leaching will get priority in the years to come.

At Vredepeel various crop rotations were laid out to reflect a range of farm conditions. The preliminary results however, show that the pesticide and nutrient inputs are relatively independent of the crop rotation, with the exception of herbicides. Moreover, the economic profitability of the systems is more determined by the cropping plan than by integrated management of the crops.

However, the major question will be the long term effects of these rotations on soilborne pests and pathogens. A major change in the objectives and set-up of the less root crop dominated system is being considered. Two changes are possible. Firstly, an adaptation in crop choice, introducing more financially high yielding vegetable crops, strictly alternating mono- and dicotylodonous crops to guarantee a quality production of the root crops and to enhance the economic perspectives. This might be the most consistent integrated approach considering the problems. Secondly, alternation of grassland and arable crops taking into account the mixed structure of the area may be interesting. This regenerative approach would offer excellent opportunities to crop high quality vegetables and to minimize problems with soilborne pest and pathogens, weeds and nutrient losses. Possibly a new lay-out will be implemented for the season 1993/1994.

Finally, the perspectives of IFS in practice can only be evaluated in practice. Management is the key-factor for the success and feasibility of an integrated approach. Therefore an experimental introduction on a number of pilot farms is considered to be an indispensable step before introducing IFS into practice (Vereijken, 1992; Wijnands, 1992).

Experimental introduction of IFS into practice

Since there is an urgent need to change production techniques in the context of increasing environmental problems, the Dutch government has supported the experimental introduction of integrated arable farming. This implies testing of the prototype systems developed at the different experimental farms by a group of experienced farmers. The major objective of this project is to explore the potential impact of the system in practice. In five regions of The Netherlands, about eight to nine farmers will convert gradually to integrated farming during the period 1990-1994. They are optimally supported by an extension specialist who is especially appointed for this and trained on a special EC-supported course (European Training in Integrated Crop Protection; ETIC) on integrated farming.

The research programme focuses on evaluation of the performance of the system and the progress that is made at economic, technical and ecological levels. Based on the experience of the experimental farm and the system's objectives, a set of demands is formulated for every region and worked out in a farming scenario in consultation with the farmers. By a contract, the participants bind themselves to this fundamental and planned conversion. During the project period, we will be able to identify any constraints for the conversion which gives a good feedback to both the development research at the farm level and to the research at disciplinary and crop levels.

Finally, research results should be optimised towards ecologically acceptable and technically feasible scenarios for regional farming and policy. After that extension and education will have the opportunity to introduce integrated production systems on a larger scale.

Development of IFS-prototypes for outdoor horticulture

Introduction

Outdoor horticulture in The Netherlands varies considerably in farm scale, crops and cropping systems. The holdings are small (2-10 ha) and concentrate around the most important auctions. Since the land is cropped with a limited number of crops, the pressure of soil- and airborne pests and diseases is high. Consequently the pesticide input is high, however increasingly ineffective. In addition high fertilizer inputs make crops more vulnerable to diseases and pests, cause too high contents of nitrate in certain produce, and pollute the environment. Prices are under pressure of overproduction and since costs are steadily increasing and the raising quality standards can often no longer be met anymore, the farm profits are decreasing. An integrated approach might solve the agronomic and environmental problems. But the economic problems probably remain, since allocated costs are just a fraction of the production value. Therefore, also the scale of activities should be enlarged by integrating horticulture with arable activities. This will also lead to the needed regional spreading of horticultural activities to prevent pests and diseases. Moreover, the high demands of exterior quality of the produce need to be reconsidered to permit farmers a less obligate use of pesticides. In the meantime research is started on the potential of IFS for outdoor horticulture.

Lay-out of the IFS-experiments

Since 1990/1991, on four regional experimental farms, located in the heart of the main production areas, four systems are being studied differing in intensity of crop rotation. The most intensive system applies to small holdings specialized in a few crops (2-4 ha), and the most extensive system applies to larger holdings (20-30 ha) integrating vegetables and arable crops. This systematic approach should provide the needed data to evaluate the potential of IFS for a range of conditions in economic and agronomic model studies.

Methods and techniques, constraints and perspectives

The IFS strategies for arable farming can also be used for outdoor horticulture. However integrated nutrient management (INM) cannot be introduced easily since inputs are crop based and largely exceed the farm output of nutrients so far. So, a fertilization strategy at the farm level is lacking. The uptake of nutrients by vegetable crops is often substantially higher than what is harvested. Consequently there is a major source of P and K in crop residues. This calls for an adapted INM strategy in vegetable-dominated rotations. Considering the low farm output and the high soil reserves of nutrients, the input will generally be limited and directed to the most demanding crops, preferably in band applications. Concerning nitrogen, it is aimed at moderate levels of available nitrogen by guided fertilization systems (Slangen et al., 1989), which also enable to account for nitrogen turnover from crop residues and green manure. New techniques to be used are band applications of fertilizers and fertigation (combined fertilization and irrigation). Adaptations in the cropping plan should prevent nitrogen losses in wintertime.

Integrated crop protection in vegetables is still hampered by a lack of knowledge particularly with regard to epidemiology in interaction with cropping measures and susceptibility of cultivars to local diseases. The crop protection strategy should include soil coverage techniques to prevent the occurrence of weeds and diseases and also nets to prevent insect attack. Integration of these techniques in practicable systems is one of the major topics for the next years. Since external quality is an essential requirement, pesticides should be substituted in a safe and efficient way.

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Policy Section

Changing policy in crop protection in various European countries

The Dutch Multi-Year Crop Protection Plan (MJP-G): a contribution towards sustainable agriculture.

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Summary

In 1987 the Dutch government announced the initiative to prepare a long-term policy plan for crop protection. This plan was to aim at optimum crop protection in all areas of agricultural management (production and trade) and open "green" space management by the year 2000. The Multi-Year Crop Protection Plan was presented in June 1991 as a "government decision" to Parliament to be debated. By the year 2000 the use of pesticides should be halved.

This article discusses the reasons and motives which have led to the decision to make the plan and treats in some detail the way chosen and the organisation needed to conceive the plan. Some remarks will be made on the targets set by the plan particularly regarding the reduction of the environmental impact of pesticides and the contribution towards a sustainable agriculture, far less depending on the use of chemicals. The feasibility of the plan is the final element of the article. Some of the planned changes will be critically considered both from a national and international perspective and in view of the necessity of support from the farming community.

The goals set by the MJP-G are ambitious, and cooperation between all participants is essential to achieve those goals. Success will only be possible with international support and committment. Not in the least a stricter regime for approval and registration of pesticides is urgently needed.

Introduction

In 1987 the Dutch government announced the initiative to prepare a long term policy plan for crop protection. This plan was to aim at optimum crop protection in all areas of agricultural management (production and trade) and open "green" space management by the year 2000. By then the use of pesticides should be halved and the then operational system of crop protection should comply with man and environment and be suitable for sustainable and cost-effective farming.

A draft of the "Meerjarenplan Gewasbescherming"(MJP-G, Multi-Year Crop Protection Plan), with these policy intentions was presented in 1990 for consideration and advice to various advisory bodies and social organisations. After adaptation of the plan especially on the subject of reforming the registration and approval policy for pesticides, the definite plan was presented in June 1991 as a "government decision" to Parliament. Brochures with the essentials of the plan as well as fact sheets on the different agricultural sectors are available in English, French and German at the Ministry.

Setting the stage

World-wide modern agriculture has developed for the benefit of food production, and in the interest of trade and export. In the Netherlands trade and export have always received much attention. After World War II this concept has led to a "boom" in agricultural production, and a shift from self-supply to export production. As a result of this policy, nowadays approximately 60% of our total agricultural yield can be exported. This can only be attained because farmers and growers apply modern technology and science. In this respect the Netherlands have been rather successful, so far. At least from a traditional economic point of view.

In spite of the relatively small area and a mainly cool and unstable climate we succeed to produce and export agricultural products as the second best country in the world. However, we do not exclusively grow crops which are natural to our temperate climate, but also foreign plants, mainly of subtropical and tropical origin in greenhouses. Dutch agriculture is thus an enviable phenomenon to those countries that hardly have been able to become self-supporting in the field of food production. But for those countries that no longer need to be taught agriculture, it is interesting to point out the consequences of intensive production in a quite susceptible ecosystem and in a small, densely populated country.

The adverse effects of the ever more intensifying agricultural production system have for a long time been ignored by the organised farming world and Dutch authorities. Only recently, under increasing pressure from the general public, the problems, which were identified and warned for as early as the sixties and seventies by scientists and environmental groups, have been recognised in official Dutch policy.

Consequences of being an "agricultural superpower"

The price that will eventually have to be paid for becoming an "agricultural superpower" has never been part of the cost-benefit balance. This price includes:

- continuing destruction of the (few) remaining natural areas in our country, and an alarming decline of biological diversity,
- pollution of air, soil and water, including ground-water for drinking water supply,
- increasing doubts by consumers about the quality of the "industrially" produced food, resulting in risk for loss of export position in West Europe, and last but not least,
- an increasing demand for raw fodder material at low costs mainly from the developing world, resulting in disruption of traditional agricultural systems, local food shortages and rising food prices in several cases. For every ha of farm land in the Netherlands, Dutch farmers exploit at least 5 ha of farm land elsewhere in the world. This leads to a gross off-balance between input and output especially of minerals and an overload on buffering capacity and explains a lot of the pollution problems caused by Dutch agriculture.

However, irrespective how we look at it, a country that wishes to modernise its agricultural systems has to use advanced techniques and methods. This implies the use of a considerable amount of fertilisers and pesticides. From our own experience we know that the more intensive the agricultural production is, the higher will be the use of pesticides. Man no longer needs to exploit natural conditions in order to control pests and diseases, but fully depends on pesticides. Farmers no longer prevent pests and diseases, simply because they permanently have a set of speedy and effective chemical weapons at their disposal. Belief in the blessings of technology has led to a situation where, for the sake of socio-economic politics in the field of agriculture, the use of pesticides became generally accepted, whereas the knowledge and skill to prevent pests and diseases disappeared.

Thus, the Dutch crop protection practice developed into a system in which pesticides had to be applied constantly in order to protect our crops from becoming infected. This idea has prevailed until recently, but now we become more and more aware of the adverse consequences, because the increasing use of pesticides inevitably means greater risks for our ecosystem, public health and working conditions.

Present use of pesticides

Compared to other producing countries the use of pesticides expressed as input per hectare per year is very high. Inputs per unit of produce are relatively low in the Netherlands, as far as figures are available for comparison. Due to being the second agricultural export nation and according to the large volume of production, the total amounts of pesticides used are, however, considerable.

Table 1. Current use of pesticides (x 1000 kg)

Soil disinfectants	9 400
Insecticides	600
Fungicides	4 500
Herbicides	4 000
Others	1 500
Total volume per year	20 000

Table 1 shows the current use of pesticides in the Netherlands. In particular the use of soil disinfectants/soil sterilants is extremely high, due to the narrow rotating schemes in potato and (flower) bulb culture. The yearly total use amounts to 20 million kilograms of active ingredients, resulting in an average of 10 kg of pesticides per hectare per year.

Table 2. Estimated use per sector (x 1000 kg)

Arable farming	14 200
Bulb culture	2 100
Field vegetable growing	1 300
Livestock farming	880
Floriculture	630
Arboriculture	500
Protected vegetable growing	470
Fruit culture	470
Parks, countryside and embankments	140
Mushroom culture	10

Table 2 gives an impression of the use of pesticides in the various agricultural sectors. On an overall basis, arable farming is the largest consumer, with bulb growing as second.

Table 3. Estimated use per sector (kg/a.i./ha/year)

Arable farming	19
Field vegetable growing	28
Bulb culture	120
Arboriculture	76
Fruit culture	20
Livestock farming	0.7
Parks, countryside and embankments	< 0.2
Floriculture	96
Protected vegetable growing	106
Mushroom culture	112

Table 3 illustrates the different inputs of pesticides per hectare in various agricultural sectors and crops. Bulb culture is absolutely in the lead, with an average of 120 kg of active ingredients per hectare per year, of which more than half are soil-disinfectants. The protected crops, as glasshouse vegetable growing and mushroom culture come in second place, both with an input of over 100 kg per hectare.

As can be concluded from these figures, it is obvious that a correlation must exist between the extreme pesticide consumption and the emission to the environment, resulting in a heavy burden of pollution. Our environment has been polluted, our drinking water wells are endangered and nature tends to lose its self-regulating capacity, whereas agriculture itself wrestles with an ever increasing number of resistant pests, diseases and weeds.

A change in Dutch crop protection policy

Under increasing pressure from the general public we have started to develop an environmental policy to cope with the multitude of environmental problems in our country. Several major policy documents were presented on the issue, most important being the National Environmental Policy Plan. As for our agricultural system as a whole the targets are set for a drastic reform in the Agricultural Structure Memorandum.

The government is convinced that an unaltered policy would have increasingly negative effects on agricultural production, on trade and export, as well as on our ecosystems. In the interest and welfare of next generations such a policy cannot and must not be accepted. Therefore, in the Agricultural Structure Memorandum of 1987 the Dutch government initiated a long-term project that has to lead to a sustainable, safe and competitive agriculture by the year 2000. This can only be achieved if ecological aspects are integrated in the total production policy. In this sense these principles can be described as follows:

- Dutch agriculture will be sustainable, provided that the self-regulating capacity of the production environment is not irrevocably affected, that the effects on the total environment are negligible and that land use is balanced in such a way, that a high quality of biological diversity is maintained.
- Agriculture can be called safe, if production as well as the way of producing are not affecting human health and welfare, and leaves enough room for our natural wildlife.
- Agricultural can be called competitive if the producers' profits solely come out of the market, if they are able to manage the cost, and moreover do not burden society, ecosystems or future generations with their expenses.

Within the scope of crop protection the Dutch government is aiming at a tangible policy, that has to lead step-wise to a situation where pesticides are of minor importance. Such a policy can be realized by means of:

- reducing the dependence on pesticides,
- reducing the use of pesticides, and
- reducing the emission of pesticides.

Furthermore it is necessary to reform the registration and approval policy of pesticides, to take into account not only risks for human beings, but also for the environment as a whole. Reduction of volume has first priority, refining and calibrating the policy of pesticide approval would follow on.

How could this change of policy be realised?

When the political decision to prepare a long-term policy plan on crop protection was taken in 1987, which meant that the more general targets of the Agricultural Structure Memorandum had to be specified, it was intended to have the plan ready by the summer of 1989. Only a few people did realise that this was an almost impossible time-table, in view of the tremendous effort that would have to be made. Analyses of current crop-growing systems, protection measures and pesticides used would have to be made. The availability and use of alternative methods and the perspectives of on-going research had to be investigated. And last but not least, the proposed measures should have to be tailored in such a way that a really feasible plan would emerge, which could for a large part be executed by the agricultural sectors themselves.

The problem was that we practically had to start from scratch. Almost all of the information would have to be gathered first, before it could be sorted out to make up the plan.

At this point I would like to mention the name of Dr. E. Goewie, the former head of the Directorate for Crop Protection of the Ministry of Agriculture. As appointed project-leader he emphasised from the onset that the plan would have to be feasible in practice and should have the support of the farming community, or else it would be a failure from the very start. The plan should not become just another policy paper with beautiful intentions that would end up on the bookshelves. Together with the members of his small project-team, he insisted that the plan should be constructed as a "joint-venture", in close cooperation with the other four governmental ministries involved, and not just as a project of the Ministry of Agriculture alone. Having made this point, dr. Goewie sought cooperation and support not only from the farming community but also from chemical industry, as well as from the environmental movement. With his inspiring view and operating in an attitude of mutual trust and cooperation he did indeed gain the necessary support vital to organise the planning operation.

The basis of the organisation that was set up to produce the plan, was formed by ten working parties consisting of experts in production, research and development, extension etc. from all sectors of agriculture. These working parties were to make in-depth analyses of crop protection for each agricultural production sector involved. On that basis they had to propose packages of measures, that could meet the realistic targets and would get enough support from the farming community to be executed. Several interministerial project-teams were formed to supervise the projects and the organisation was headed by a Steering Committee consisting of high level officials of the five ministries involved. During 1988-'89, when the plan was designed in detail, more than 150 people were working on it.

In spite of this effort and partly due to the wish of Parliament to include a socio-economic analysis of the consequences of the plan for the viability of the various agricultural sectors, the process suffered some delay. Instead of 1989 it was by the end of the summer of 1990, that the plan was presented to society for consideration. But, considering the tremendous amount of work that has been done, the delay was amazingly short, and the whole planning operation can be viewed upon as efficient and successful.

From policy change to realisation in practice

Is the Crop Protection Plan a feasible plan and will it get enough support, particularly from the farming community to be executed in practice? In short: will it work? One complicating factor is that the initial volume approach, to drastically reduce first of all the quantity of pesticides used, was frustrated in the final phase of planning, due to mistrust at the Ministry of the Environment that the volume approach would work. They insisted that a strict active regulating (substance) regulating policy was included in the plan and that at short notice the admission of all chemicals that could not stand the environmental tests would be ended. On the political level this was agreed upon, but the result was an obvious tension in the plan. It seemed impossible to gradually reduce pesticide use, while at the same time prohibiting pesticides that - for the time being - were crucial to make a successful transition possible in agriculture.

In the public response to the plan, the opinions and advices stressed this point too. Although there was a critical but positive response to the plan, in which the analysis of the problems and the ambitious goals were welcomed, many responders doubted the feasibility of the plan, because of the tension in volume and substance related targets. The farming community, as well as trade and chemical industry, could underwrite the major objectives of the plan, particularly on the point of volume targets, but insisted that more time was needed to reach the goals. The proposed strict regulating policy was considered as much too tight, which could lead to the failure of the plan as a whole. On the other hand, environmental and consumers' groups stated that the reductions should be reached much faster and that pesticide regulation should be tightened much sooner.

In view of the public response several adjustments to the plan have been made, for instance, concerning the admittance and approval policies on pesticides. Of course, the adjustments have not been satisfactory to all groups involved, but sufficient support for the plan remained to be executed.

Practical problems in implementation of the new crop protection policy

It will, however, take a great effort of all those involved to implement the plan. The practical difficulties are enormous indeed. I will only dwell on some of them. It should be realised that carrying out the proposed policies implicates that the step-wise reduction of pesticide consumption has to be coupled with alternative non-chemical crop protection methods. At the national level we are, therefore, striving to improve the growers' phytosanitary know-how by education and extension. But, such a development should not be restricted to one single country, because it is a world-wide responsibility. The stricter the import requirements with respect to pests and diseases, the greater the use of pesticides. In particular when stimulating biological control, it is absolutely fatal for our efforts in creating a healthy environment if demands for zero-tolerance are not adjusted.

However, it has to be admitted in all fairness that these problems are probably of no concern to trade and export. One of the consequences of a more liberal import policy could be a greater risk of introducing pests and diseases, thus leading to the vicious circle of stricter foreign demands with respect to phytosanitary and phytopharmaceutical matters.

We are convinced, however, that in cooperation with all participants the necessary efforts can be made and that the ambitious goals set for the year 2000 will be achieved. A point of great concern is the difficult task of ending the use of those pesticides, which from an environmental point of view, no longer can be accepted. This process of updating the current set of pesticides, by finishing admission of up to a 1000 or more current applications of some 90 active substances, while at the same time approving and admitting newly developed chemicals, which stand the environmental test, will be a very difficult operation. For some of these applications of specific substances there are no alternatives, chemical or other, available yet, but still the policy target is that the operation has to be finished by the year 2000. Only under strict conditions exceptions to the rule will be tolerated, so as to ensure that agriculture has the incentive to develop alternatives as soon as possible.

Conclusions

It is needless to point out that our national policy to reduce the use of pesticides and to apply a stricter regime for admittance and registration can only be successful, if we can get international support and commitment. The world simply has become too open and too small, to do these things as a single nation. Changing crop protection and pesticide policy should at least be harmonised at the European Community level. One gets pessimistic about the way things are being worked out at the moment. For the Netherlands the recent EC-agreement on harmonisation of pesticide approval, still holds a risk of a set back in the execution of the Crop Protection Plan, because (many?) environmentally critical substances might stay on the market. But let us bear in mind, that crop protection can and must never be seen as an isolated activity. Alternative crop protection methods can only be introduced successfully on a large scale if the agricultural system as a whole, and hence individual farmers get enough economical room from politics.

If the idea of "impossibility" of change for economic reasons alone keeps on prevailing in politics, it will lead to the inevitable dead-end of our agricultural production system with a disastrous negative environmental impact as a consequence. It is a negative spiral that works both ways, by further boosting production the environmental burden will increase and changes will become even more impossible to realise. The Dutch policy plan for the reduction of pesticide use is just one step of many that are necessary in all fields of farming to cope with the environmental problems. Eventually a sustainable agriculture will only be possible if inputs are drastically lowered and land use comes more into balance with natural buffering capacities.

Documentation

The various plans and memoranda discussed above are presented in the following list. For those who are interested summaries in english are obtainable from the Netherlands Ministry of Agriculture (see list of participants for full address).

- Nota: "Naar een taakstellend meerjarenplan voor de gewasbescherming", 1987, Ministerie van Landbouw en Visserij. (To a Multi-Year Crop Protection Plan)
- Structuurnota Landbouw 1987/1990, Tweede Kamer, '89-'90, 21148, nr. 2-3 (Agricultural Structure Memorandum), summary in english available.
- Nationaal Milieubeleidsplan, 1990, Tweede Kamer, '89-'90, 21137, nr. 1 en 2 (National Environmental Policy Plan), summary in english available.
- Meerjarenplan Gewasbescherming (beleidsvoornemen), 1990, Tweede Kamer, '89-'90, 21132, nr.39. (Multi-Year Crop Protection Plan: Policy Intentions).
- Meerjarenplan Gewasbescherming (Regeringsbeslissing), 1991, Tweede Kamer, '90-'91, 21677, nrs. 3-4 (Multi-Year Crop Protection Plan, Government Decision), summary in english available.

Limited use of pesticides: the Italian commitment

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Summary

At present more than 6000 commercial formulations derived from 400 active compounds have been registered in Italy, but only one hundred of them are important in current crop protection practices. In recent years pesticide legislation became more stringent and severe, and research efforts towards alternative methods to replace chemical control and protection were intensified.

In 1987 the Italian Interministerial Commission for Economic Programming approved the realization of the "National Integrated Control and Protection Plan" to be implemented by the Ministry of Agriculture and Forestry with the participation of the regional authorities. The final aim of the plan is to reduce the use of agro-chemical products in agriculture along four lines: a) management and control of the use of agro-chemical products, b) encouraging the production of agro-chemical products compatible with the environment and the health of the consumer, c) optimization and large-scale use of alternative control methods and d) promotion abroad of a "quality image" of Italian agro-food produce. These initiatives should lead to a reduction of 30-50% in the use of agro-chemical products.

Details of the execution of the plan are described from three different points of view: regulatory, scientific and social. In the appendices a detailed overview is given of all the projects within the frame of the above-mentioned national plan.

Introduction

In Italy the use of pesticides has been common practice since 1948. It has been limited to a rather small number of active substances until quite recently, when hundreds of new products appeared on the market. At present more than 6000 commercial formulations derived from approximately 400 active compounds have been registered in Italy, but only about one hundred of them are important. Many have related chemical structures and/or show similar action patterns.

Although the highly diversified and specialised agriculture now existing in Italy requires accurate and prompt agro-chemical treatments there has been an approximately 6.5% reduction in the use of pesticides since 1980. This decrease can largely be attributed to the use of new, more effective products requiring smaller dosages.

Fungicides represent approximately 50% of the products used, but are the least toxic to man. Insecticides, the use of which has remained constant in recent years, account for 25% and are the most toxic pesticides. The most notable development has been in the use of herbicides, with an increase to 16% of the total volume of pesticides used, which is partly due to the difficulties of continuing to apply cultivation methods because of the high cost of labour.

The fear of upsetting the biological equilibrium by the use of agro-chemical products, and above all the concern about their residues, led to the first regulatory measure in Italy (Reg. no. 283 of 30 April 1962: "Hygiene Regulations on the Production and Sale of Food-stuffs and Beverages"). However, it was the D.P.R (Presidential Decree) no.1255, dated 3 August 1968 (controlling the production, trade and sale of agro-chemical products) that primarily dealt with the legislative regulation of the whole field. In the following years many active substances considered as harmful to man and the environment were banned.

While pesticide legislation became more stringent and severe, research efforts towards alternative methods to replace chemical control and protection were intensified. On 9 January 1965, the "Research Group for Integrated Control and Protection against Plant Enemies" was formed within the framework of the Italian Commission for Agricultural Science of the National Research Council (CNR). The objective of the group was to rationalize crop protection by adopting **all** the techniques available, not only those pertaining to agro-chemical products. The financial assistance from the EC and the Italian Ministry of Agriculture and Forestry, and the scientific collaboration with the IOBC/WPRS, have helped in achieving significant results, even though the use of agro-chemical products is still high.

Following the governmental regulation of 8 February 1985, bringing into force the EC directives on the quality of drinking water, the groundwater in some areas has been found to be below the decreed standards, thus creating problems in the supply. This has forced the Italian Authorities to take action against the use of herbicides and to develop an overall plan to control the contamination by agro-chemical products. The issue has been faced from three points of view: **regulatory, scientific and social.**

Regulatory aspects

The Italian Interministerial Commission for Economic Programming (CIPE), through the decree of 23 April 1987, approved the realization of a "National Integrated Control and Protection Plan" to be implemented by the Ministry of Agriculture and Forestry with the participation of the regional authorities, according to Reg. 752/86.

The final aim is to reduce the use of agro-chemical products in agriculture, and the following objectives have been established:

1. management and control of the use of agro-chemical products,
2. encouraging the production of agro-chemical products compatible with the environment and consumers' health through the development of cooperation between the agro-chemical industry and the agricultural area,
3. optimization and large-scale use of alternative methods (other than chemical) for the control of pests, diseases and weeds,
4. promotion abroad of a "quality image" of Italian agro-food produce.

Together, these initiatives should lead to a reduction of 30-50% in the use of agro-chemical products.

ad 1. Management and control of the use of agro-chemical products. With regard to this objective, an information system has been set up for the users of agro-chemical products to enable them to decide which control and protection methods should be used. This system is already partly in operation. It consists of a data bank of agro-chemical products, established by the Ministry of Agriculture and Forestry with the collaboration of the Experimental Institute for Plant Pathology of Rome. The data are put into the SIAN (National Agricultural Information System) established by the regulation of 4 June 1984. Agricultural organizations and public institutes also have access to the system.

The regional authorities have formed techno-scientific teams consisting of experts whose duties are: to assist in the management of agricultural enterprises and to promote innovations in the field of control and protection. This activity implements EC Reg. no. 270/79 for the formation of Agricultural Extension Specialists (Divulgatori Agricoli Specializzati "DAS" and

Polivalenti "DAP") through four inter-regional associations for the training of extension workers. The project is financed by the EC, the Italian government and the regional authorities. Centres are being set up with the objective of keeping extension workers up to date with the latest research results. The extension specialist acts as an intermediary between research and the farmers: in responding to the requests made by the latter for innovations he can commission research.

The Ministry of Agriculture and Forestry is responsible for the formation of the research centres, operating through some of its agricultural research and experimental institutes, e.g., those specialised in citrus culture, olive culture, soil-borne pests and diseases, viticulture, plant pathology and fruit cultivation.

Again within the framework of EC Reg. no. 270/79 a teletext system (AGRIVIDEOTEX) has been set up to provide farmers with information on irrigation, phytopathological control, economic management, innovative developments, etc.

ad 2. Encouraging the production of safer agro-chemicals. This objective requires collaboration between the chemical industry and the agricultural area. The major goal is to make a more rational use of agro-chemical products, rather than promote their use on purely commercial motives. To attain this objective a "Rural Register" (quaderno di campagna) will become compulsory (Ministry of Health Decree no.217, 25 January 1991) and a network for the monitoring of residues will be set up (Ministry of Agriculture and Forestry Resolution of 3 September 1988).

The Rural Register has to be kept by all users of agro-chemical products and should contain data with on the location of the agricultural enterprise, the area (in hectares) treated with such products, the type of crops treated and the area they cover, the quantity of pesticides purchased, used and remaining in storage at the end of the year (with trade name and registration number). The register is intended to be an instrument for educating the grower and increasing his responsibility in the use of agro-chemical products. It also makes possible technical and scientific analyses which are used to guide both treatments and production of agro-chemical substances. The data in the Rural Registers will be used to: -update the public institutes by providing information to be taken into account when programming projects on control and protection; -assist the extension specialist in performing his work; -aid the institutes that carry out monitoring of residues and those responsible for evaluating the impact of agro-chemical products on the environment.

The national network to collect data on residues requires the creation of five sampling centres (North, Centre and South of the Italian Peninsula, Sicily and Sardinia). In collaboration with the producers' associations the centres will collect the samples and send them, together with the relevant information, to specialised laboratories for checking. The collected data will then be sent to the Experimental Institute for Plant Pathology of Rome for techno-scientific analysis and then forwarded to the relevant authorities of the Ministry of Agriculture and Forestry, who can then take action, if necessary.

ad 3. Optimization and large-scale use of alternative methods. This objective will be treated hereafter under "scientific aspects".

ad 4. Promotion of a better-quality image. The combination of the above-mentioned operations (Rural Register and Residue Monitoring Network) will contribute to achieving this objective.

Scientific aspects
On 16 March 1988 (Reg. no.37) the Ministry of Agriculture and Forestry approved a research programme on "Biological and Integrated Control and Protection of Crops and Forest Trees".

Because of the great technical and economic significance of crop protection in agriculture it is still very difficult (and this will remain so in the near future) to substitute chemical methods of control and protection with biological methods. Consequently, greater priority is given to a harmonised use of both supervised and biological control (=integrated crop protection) to attain the acquisition of new and more rational methods. Supervised control will be based on chemical treatment, taking into account the requirements of both production and the environment. "Calendar routine" spraying will be excluded, whilst maximum consideration will be given to pathogenic and economic "thresholds of intervention".

The research project aimed at the "biological and integrated control and protection of crops and forest trees" is now in its third year of operation. It takes into account the latest experiences and results in Italy and calls on the collaboration of the numerous research institutes active in this area. The project is divided into **sub-projects** aimed at studying the application of integrated control in the various areas of agriculture such as fruit-growing, viticulture, olive culture, citrus culture, protected crops and forest trees (see appendix I). These areas not only represent some of the most significant areas of production in Italy but also those subject to problems arising from residues. In particular, studies will be undertaken on the following subjects:

- biology of the "target organisms" to be attacked (pests, diseases, weeds, etc..);
- relationships between hosts, their parasites and their environment;
- non-chemical protection methods (agronomic, physical, biological, etc.).

The above-mentioned studies should lead to new information on e.g.:

1. definition of the key pest species of each crop and determination of the "threshold of economic damage", as well as optimization of forecasting models,
2. optimization of monitoring techniques to timely detect resistance to agro-chemical products occurring in pests, diseases or weeds, as well as determination of the environmental "risks" caused by the chemical methods used to keep the pests below the damage threshold,
3. innovative methods and strategies against the main types of pests, diseases and weeds.

Because of its importance, the subject "biological protection and control" (see appendix II) receives particular attention. The aim is:

- to identify new natural enemies in agricultural and forest ecosystems,
- to import exotic antagonists of insect pests, pathogens and weeds,
- to increase the use of biotic agents in the biological control of pests, pathogens and weeds, and
- to evaluate the side effects of agro-chemical products on beneficial organisms in agriculture.

To summarise: within the project one can distinguish **sub-projects** aimed at short-term solutions of problems in specific crops, and research groups for the study of questions requiring more thorough investigations and special techniques and/or methods. In this case the results of these studies are not immediately applicable but can provide the basis for a more correct, and less environmentally harmful, system of crop protection.

To evaluate the project over the first two years a series of study days has been arranged for the presentation of results so far obtained. So far 209 scientific papers and reports have been produced within the framework of the project over the first two years: Viticulture 38 , Fruit

Culture 8, Olive Culture 25, Protected Crops 11, Forest trees 31, Biological Protection 39, Residues 37, Weed Control 18 and The Bee as a Test Insect 2.

Social aspects

Taking social aspects into account, the authorities intend to guide the consumer's choice and to provide correct information to the public about the real risks which may be caused by agro-chemical products. Consumers need to know that:

- if they want agricultural products outside of their normal growing season, this implies forced-growth (premature production) or protective treatments of the plants (preserved produce) which cannot be done without the use of chemical substances,
- if they want agricultural products to be 100% perfect, this requires massive use of agro-chemicals; thus it is much better to accept a slightly inferior quality,
- if they have a large demand for agro-chemical free products, it can lead to an excessive amount of products labelled so-called "biological" (thus giving higher prices) being marketed without any checks or inspections of the production process. This can also make the efforts of honest people futile
- sound and well-balanced agricultural practices assure that the risks due to agro-chemical residues remain within acceptable limits.

Appendix I

Outline of major activities of the sub-projects

The sub-project on viticulture is coordinated by the University of Milan. The objectives are:

1. Development of innovative strategies against the principal fungal diseases. This concerns studies on:
   a. mechanism of fungicide action and integrated protection plan,
   b. models for forecasting epidemics,
   c. biological protection against *Botrytis cinerea,*
   d. influence of agricultural techniques on the course of epidemics.
2. Integrated protection against the grape moths. This comprises studies on:
   a. distribution of moths in vineyards and factors controlling the relationship between *Lobesia botrana* and *Eupoecilia ambiguella,*
   b. optimization of the application time of microbiological preparations and/or growth regulators to control the herbivorous generations,
   c. protection techniques based on mating disruption by means of sex pheromones.

The sub-project on olive culture is coordinated by the University of Pisa. The objectives are:

1. Study of the influence of agricultural practices and different management methods on the phytopathological conditions of olive cultures.
2. Optimization of monitoring techniques to estimate infestation levels.
3. Determination of the dynamics of phytophagous populations in relation to biotic and abiotic limiting factors.
4. Study of the feasibility of traditional control methods and protection methods using limited quantities of active ingredients or low-toxic products.
5. Potentials of application of biological control strategies.
6. Implementation of forecasting models to correctly and rapidly determine the moment of application in different olive-growing areas.

Species to be studied: *Dacus oleae*, *Prays oleae*, *Saissetia oleae*, and the fungus, *Spilocaea oleagina*.

The sub-project on fruit culture is coordinated by the University of Bologna. Its objectives are to perfect the methods of integrated protection, presently carried out partly in apple and peach orchards and to a limited extent in pears. The main topics concern:

1. Determination of the action thresholds for different noxious insect species, and refinement of those already used.
2. Validation of the information obtained from sampling methods, such as the capture/infestation ratio in the case of sex pheromone traps, etc..
3. Increase in the use of entomophagous species through optimization of application techniques.
4. Increase in the use of insect pheromones for control.
5. Introduction of agents with low toxicity and/or with limited environmental side effects.
6. Development of epidemiologic models for cryptogams.
7. Study of the effect of fungicides on beneficial insect populations.

The above-listed topics will be divided over the various fruit crops as follows:

Apple

a. re-introduction and protection of phytoseiid mites,
b determination of the action threshold of *Argyrotaenia pulchellana*,
c. application of the mating disruption method against *Cydia pomonella*;
d relationship between infestations of woolly apple aphid and clearwing moths, and the possibility for control of the latter moth with mass trapping by means of pheromones,
e. biological protection against the San José scale by means of parasites (*Encarsia perniciosi*) and predators (*Stethoris* sp),
f. tortricid moths: improvement of sampling techniques, capture/infestation correlations, threshold determination, alternative hosts and mortality factors,
g. improvement of sampling methods for *Leucoptera scitella* and *Zeuzera pyrina*,
h. identification of the parameters (Mills index, inoculum potential, host receptivity) necessary to develop a forecasting model for apple scab.

Pear

a. effect of fungicide treatments on populations of *Psylla*;,
b. determination of the action threshold for tortricid moths,
c. evaluation of the damage caused by aphids and determination of the damage threshold,
d. etiological and epidemiological study of brown spot,
e. biological control and integrated protection against diseases.

Peach

a. rationalisation of protection against the peach scale, using pheromones,
b. possible significance of the presence of various species of aphids in different growing situations,
c. use of pheromones for protection of the peach twig borer,
d. investigation of the susceptibility of different peach varieties to the Mediterranean fruit fly and of the capture/infestation ratio for different types of traps,
e. study of possibilities for integrated protection against *Cytospora* and *Fusicoccum* canker.

The sub-project on citrus culture is coordinated by the University of Catania. Its major objective is rational protection of orange, clementine and mandarin. There are two principal themes:

1. To improve understanding of the key-pests and -diseases by studying action thresholds for the most important phytophagous organisms and their population dynamics.
2. To improve understanding of the relation between phytophagous and entomophagous organisms in order to control infestations by establishing a reliable biological and integrated protection method.

The satisfactory results so far obtained with regard to the integrated control in lemon orchards encourage the above-described research.

The sub-project on protected crops is coordinated by the Experimental Institute for Agricultural Zoology of the Ministry of Agriculture and Forestry at Rome. The utilization of plastic material to cover greenhouses and tunnels, and mild winter conditions of the southern regions, have encouraged a rapid expansion of ornamental and vegetable growing in Italy.

A protected environment, particularly when heated, represents an ideal habitat for many noxious insects in vegetable and flower crops. Absence of a cold period during winter and the high humidity and temperature encourage phytophagous insects to develop and reproduce very quickly, necessitating frequent applications of pesticides.

The sub-project for this sector includes the following basic objectives :

1. Solution of soil-borne pathological problems. Disinfection of the soil is necessary to reduce damage, thus soil disinfectants represent 67% of the total volume of pesticides used for the defence of protected crops. Hence the sub-project will study heat efficiency (solarization and air/water-vapour mixtures) and the utilization of cultivation methods "without soil", as alternatives to chemical treatments.
2. Optimization of cultivation techniques that can limit fungal leaf infections and stimulation of the use of parasitoids and predators of phytophagous insects in vegetables (tomato, zucchini, pepper, aubergine).
3. Determination of the damage threshold for key-pests and -diseases of chrysanthemum and of a few short-cycle flowering plants, by implementing straightforward sampling methods applicable in greenhouse cultures.

The sub-project on forestry is also coordinated by the Experimental Institute for Agricultural Zoology of the Ministry of Agriculture and Forestry in Rome. In Italy 6,365,000 hectares, which is about 21% of the national territory, are covered with forests. Coppice prevails over high woods, of which nearly half consist of conifers (spruce, larch, different species of pine, Douglas fir, Atlas cedar, cypress) flanked by hardwoods including different species of oak, beach and chestnut.

Next to supplying the wood industry, over a large part of the mountainous and hilly country of Italy the forests have fundamental importance for hydrogeological protection, the biological equilibrium, as well as the production of oxygen and pure air. However, the forests are being impoverished by various parasitic infestations and/or infections, which under ideal conditions can threaten the survival of particularly susceptible tree species. It is not practicable to use pesticides for forest protection. Sylvicultural methods and biological protection in its widest sense are the systems which should be adopted. The sub-project deals with the plant protection problems and is aimed at:

1. Verifying whether natural and/or synthetic pheromones can be applied in forecasting the leaf defoliation caused by Lepidoptera in coniferous trees and hardwoods.
2. Use of biological insecticides to prevent forest defoliation and their eventual effect on the population dynamics of beneficials.
3. Study of the biology of bark beetles and other harmful xylophagous insects in different forest areas.
4. Study of the possibilities of integrated protection against pathogenic microflora present on conifer seeds.
5. Etiological and epidemiological investigations in seedling nurseries.
6. Biological protection against chestnut canker with hypovirulent isolates of the same pathogen.
7. Study of biology and possibilities for biological control of root rot.

Appendix II

Outline of major activities of the research groups

The research group on biological control and protection is coordinated by the University of Naples. Its principal objectives are:

1. Identification of new biotic antagonists applicable in agricultural and forest ecosystems:
   a. insect predators and parasites of phytophagous insects,
   b. phytoseiid predators of phytophagous mites,
   c. evaluation of the significance of entomopathogens in agriculture and forestry,
   d. fungal antagonists of nematodes.
2. Introduction of exotic antagonists of pests and diseases such as:
   a. natural enemies of *Aonidiella aurantii* and other Diaspididae,
   b. natural enemies of *Hyphantria cunea*,
   c. natural enemies of scale insects,
   d. natural enemies of phytophagous organisms of Mediterranean crops.
3. Mass-rearing techniques and the utilization of biotic agents in biological protection (Neuroptera, Syrphidae and other Diptera, Phytoseiidae, Hymenoptera).
4. Methodology to evaluate the side effects of chemical pesticides on the useful organisms in agricultural ecosystems and to identify resistant strains especially:
   a. side effects of chemical pesticides on phytoseiid mites,
   b. side effects of pesticides on parasitic Hymenoptera, Coccinellidae and on bees.

The research group on residues is coordinated by the Experimental Institute for Plant Pathology of the Ministry of Agriculture and Forestry at Rome. Despite ample documentation supplied by industrial companies for pesticide registration, complete information on actual use is usually lacking. The quantity of residues can be influenced by agricultural methods, atmospheric agents and by interaction of the chemical agents. Verification of these different factors is one of the responsibilities of the group. It also has the duty to forecast the destination in the environment of agro-chemical products by means of simulation models.

Another task is to supply, through analysis, information on the contamination by agricultural products in soil and water resulting from currently used agricultural methods. The information will enable the group to identify those areas which immediately require biological control and integrated protection.

Attempting to limit pollution due to agro-chemical products, the group verifies also the validity of the control methods and integrated protection systems proposed by the sub-projects described in Appendix I. It collaborates with the following sub-projects : "viticulture", "fruit culture", "olive culture", "citrus culture" and "weed control".

The research group on weed control is coordinated by the University of Bologna. The use of chemical herbicides has caused a revolution in agricultural techniques, in particular in the use of labour. The large number of herbicides make it possible to apply them in a wide range of crops for many weeds, and there is a rich choice of methods and times of application.

From the viewpoint of contaminating agricultural products herbicides create few problems as they are generally used early in the season. However, the main problem of the herbicides is that they cause much environmental damage due to accumulation problems. They possibly cause pollution of the groundwater.

The research group aims at collecting more information on weeds such as their biology, variability, the selection of forms which are gregarious in the different types of crops, their threat to crops, etc. The study of the efficiency of control treatments, phytotoxicity, and the most appropriate doses will make a rational utilization of chemical products possible. The control of pollution, in collaboration with the research group on "residues", will permit a well-balanced selection of those herbicides that cause the fewest problems.

Another objective of the group is to study systems of alternative protection (mulching, heat sources, especially if applied over small areas, as in protected crops), with a preference for biological solutions.

The research group on the Bee as a test insect for agricultural pollution is coordinated by the Experimental Institute of Agricultural Zoology of the Ministry of Agriculture and Forestry at Rome. In recent years, the worrying death-rate of bees in various Italian regions has been proven to be caused by improper use of agro-chemical products. This demonstrates the sensitivity of bees to certain chemical products, whereas their special biological and behavioural characteristics make them ideal organisms for environmental monitoring experiments. They form now an indispensable instrument to evaluate the environmental impact of agro-chemical products.

This method requires permanent stations each equipped with a pair of beehives in which the death-rate will periodically be surveyed. If the number of dead bees collected in traps (Gary-type) exceed 500 specimens in 7 days, further action will be taken. This involves inspection of the dead specimens through laboratory analysis to determine the possible presence of pesticides.

The main research objective is to improve the current methodology to establish the causes of mortality (natural or artificially caused) and new analytical methods.

Crop protection policy in Sweden: a retrospective view and some thoughts for the future.

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Summary

The current crop protection policy of Sweden is reviewed. Main reasons are provided for the development of an Integrated Pest Management (IPM) of: the role of the consument. Special attention is paid to the importance of environmental matters, (the role) of consumer pressure, the reactions of the pesticide industry and the farmers' organizations.

The first developments in IPM and biological control in Sweden were initiated as a result of environmental concern of the general public and interest of devoted scientists, and not of anticipative politicians or research administrators. The current environmentally based crop protection policy, however, is funded on a clear political concept. Harmonization with EC regulations will mean the development of a production inspection and of certification schemes. The impact of the European market on agriculture in Sweden will probably favour the development of IPM programmes.

Current crop protection policy in Sweden

Since the Second World War the Swedish agricultural policy has been aimed at the development of a more efficient production and at an income of farmers comparable to that of industrial workers. This policy led to rapid restructurization of agriculture and to intensive production systems like in most western countries.

The Swedish parliament has recently set up a long term programme to minimize pesticide risks in agriculture, horticulture and forestry. In 1986 a decision was taken that the quantity of pesticides should be halved by 1990, i.e. a reduction from about 4,500 to 2,250 tonnes active ingredient per year should be achieved. At that time there was enough information available to assure the politicians that this was a realistic goal. The relevant governmental bodies, the Board of Agriculture, the Chemical Inspectorate, the Environmental Protection Board and the Board of Industrial Welfare, supported by additional funds, designed a programme, and the goal of 50% pesticide reduction was reached in 1990.

The main points contributing to the success of the programme (to reduce pesticide use) were the development of administrative procedures, the provision of guidelines and training, extended monitoring of pesticide residues and technical improvements leading to a lower pesticide consumption.

Administrative procedures

- careful reanalysis of previously permitted registrations
- extended requirements for new registrations and registration renewal
- withdrawal of certain pesticides
- transition to preparations causing fewer risks and from broad-spectrum pesticides to low dosage pesticides with selectif action
- restriction in use of a number of pesticides to professionals

- improvement of risk/benefit analysis of pesticide use

Guidelines and training

- improved planning of crop production and pest control
- safer storage of pesticides
- safer handling of pesticides (improved procedures for application, filling and cleaning of spray equipment, etc.)
- training and handling of pesticides for some 30,000 farmers for one or three days during a three-year period.

Pesticide residues

- development of new methods for analyses of residues of pesticides
- extended programmes for monitoring pesticide residues

Elements leading to reduced use of pesticides

- use of lower dosages, particularly in herbicides
- reduction of the number of applications
- taxing of pesticides
- performance tests of pesticide spray equipment
- voluntary tests of spray equipment in operation
- promotion of organic farming

Although IPM and biological control were not mentioned explicitly as major tools in the governmental programme concerning the new plant protection policy, in reality our five plant protection centres were reinforced to make it possible to develop a better extension campaign in order to provide better information about risks, pest and disease forecasting in agricultural crops and biological control in greenhouses.

In the autumn of 1990 the government authorities were asked to design a plan for further reduction of pesticide use to a 25% of the 1985 level. This is expected to be more difficult to achieve than the first reduction of 50%.

Main reasons for the development of an IPM friendly policy

Biological control has been applied quite extensively in the horticultural industry in Sweden. Also selective pesticides against aphids have been used in agriculture. But as I see it, it was not a governmental initiative which led to the use of IPM in Sweden. I will summarize the reasons leading to initiation of IPM in the following.

Influence of environmental issues

To understand the development of IPM we have to go back some 30 years to the days of Rachel Carson's "Silent Spring". Several important mistakes were made by people working in chemical industry, agriculture and plant protection services of Sweden at that time. The first and most serious of these "affairs" was the dressing of seeds with alcylic mercury, resulting in the poisoning of birds and fish. The mercury compounds accumulated in the food chain. Another much disputed pesticide was 2, 4, 5 T sprayed from airplanes against broad-leaved trees and bushes in replanted woods. In addition, also the negative side-effects of DDT became appareur.

It is sad to say that the "experts" often ended up with defending a hopeless case, "helping" agriculture as they probably thought. The media focussed their attention on these affairs and so, gradually, "poisons" in agriculture and forestry became an important issue first in public and later in politics.

Already in the seventies the successive ministers of agriculture expressed the need to minimize the use of pesticides and the demand for a policy which would result in long-term sustainable crop production. Funds were allocated to the Agricultural University for research and development of IPM. Several projects were initiated, e.g. those dealing with IPM in orchards and the use of predaceous mites and parasitic insects in greenhouses. Some years earlier the ideas about economic thresholds had resulted in research programmes and the start of forecasting work in South Sweden. But as a result of governmental subsidies to the farmers based on their yields instead of environmentally safer production, they did not have any incentive that led to a reduction in pesticide usage.

Although only few casualties occurred due to pesticides, the public developed a strong awareness about the potentially serious detrimental effects of pesticides on the environment, and Swedes are known to be very much concerned about keeping nature unpolluted. Environmental issues, therefore, played a major role in the awakening of the politicians and conception of a new plant protection policy in Sweden.

Consumer pressure

It was not before the eighties that the demand for products grown "without poisons" started to increase. Since then this market has been growing slowly, but at the same time has been quite sensitive to overproduction, partially because of problems in logistics and distribution of the products.

Policy changes, chemical industry and the farmers

The changes in policy with regard to restricted pesticide use were in general opposed by the pesticide industry, but supported by farmers' organizations who realized that if pesticides were dangerous, farmers were the first to be affected.

Present-day use of IPM

Examples worth mentioning here are a) substantial use of selective pesticides against aphids in arable crops, b) predominant use of biological control in greenhouses with vegetables, at present also extending to pot plants, and c) integrated production of apples and pears. The main reasons for starting to use IPM were:

- the general public shows a thorough understanding of the need for a safer plant protection policy
- people now working in agriculture have been educated at schools and universities where great emphasis has been put on alternatives for chemical methods, and on the negative side-effects of pesticides
- although only few research and development programmes were specifically targeted at development of IPM and to generate the competence needed in practice, the commitment of people involved should not be overlooked
- the successive failure of pesticides because of resistance of pests in greenhouse crops provided the economic impulses and interest to change to biological control methods
- this was followed by a rapid development of companies which supplied the market with the bioagents needed in IPM
- finally, the transfer to IPM was stimulated by a general policy to minimize the use of pesticides.

Influence of national developments and harmonization of rules within the EC

At this moment the basis for further development of IPM should be favourable in Sweden, both in technical as in political aspects. However, there are some general agricultural developments which cause that growers lack confidence in the future. First of all, agriculture is forced to reduce production within a few years. Presently some 500,000 ha surplus land is set-aside, without any obvious economic use. Further, more prices of agricultural products for the farmer will fall, eventually drastically (e.g. for winter wheat in Sweden prices will go down from SEK 1.40 to 0.90 per kg). In addition, the economy of Sweden is in regression and few people are willing to take initiatives for necessary reorganizations, which results in fewer investments to innovate.

Will the harmonization of rules within the EC influence the state of affairs in Sweden? Sweden has applied for membership of the EC. The harmonization process of the Swedish society is already under way. It is, however, hard to predict the outcome of this process. The EC legislative process is in a very dynamic phase. Sweden was early in using environmental levies on products detrimental to the environment. Use of levies is now also discussed within the EC. But harmonization of regulations alone will probably not strongly influence the development of IPM in the EC. The market situation with its surplusses of today or shortages of tomorrow is expected to have a much more powerful impact on future trends in IPM. Politics, and therefore policies, are also depending for a large degree on market developments.

When Sweden joins the EC it means that plant protection regulations will be harmonized. The way of production of several crops will have to face the demands of certification schemes. Prices of products will not fall as rapidly as presently, which may lower the need for IPM. There will be more optimism amongst farmers, and more impulses to innovate. The Swedish Chemical Inspectorate will have to adapt its demands to EC standards, which might mean a lower pressure on the reduction of pesticide usage. At the same time there might be a more rapid access to new compounds needed in IPM programmes, which is an important limitation today. Hopefully the resulting better economy in Sweden after joining the EC will make it easier to raise financial support for development of IPM and Integrated Farming programmes. Improvement of biological control and IPM programmes will be stimulated through the open market with the continent where IPM is applied on a considerable area. The prices of pesticides and other agricultural inputs are expected to fall. There are currently high taxes on fertilizers and pesticides in Sweden. The price reduction will make it easier for the Swedish farmer to cope with the strong international competition. But, at the other hand, it might also lead to increased use of these inputs.

Concluding remarks

After having discussed the factors and developments which might negatively or positively influence implementation of IPM, it is now appropriate to estimate what the trend will be. Will funds be raised in Sweden to have more IPM programmes? Will IPM be accepted as a general crop protection policy and will it be written into the regulations? It is expected that the further reduction in pesticide use to 25% of the 1985 level will indeed encourage development and implementation of IPM. In addition, may be even more importantly, market demands in the EC for products with lower residue levels might form a stimulus for IPM.

If IPM will prove to be economically competitive and environmentally safer, it will have a promising future. A joint effort within the EC on research, extension and implementation of IPM would make it easier to (achieve the goal of) move to sustainable agriculture.

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L'évolution de la politique[1] française de protection des plantes des 50 dernières années.

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Résumé

La politique en matière de protection des plantes a été le resultat, depuis la création du service français de Protection des Végétaux en 1941, d'un équilibre entre la politique agricole générale et la politique de la santé publique. L'orientation productiviste de la politique agricole, la mise en place de la politique agricole commune dans la CEE et le développement rapide de la phytopharmacie, ont favorisé jusqu'au début des années 70 l'extension de méthodes systématiques de protection sur l'ensemble des cultures.

Cependant l'apparition déséquilibres dans l'écosystème des vergers ou de phénomènes de résistance de certains insectes, ont conduit le ministère de l'agriculture à mettre en place des essais de lutte intégrée en verger à partir de 1967. Complétées par des stages de formation organisés par l'ACTA, ces actions démonstratives et de développement n'ont pas provoqué une très grande extension de la lutte intégrée proprement dite. Mais par contre elles ont contribué à une prise de conscience des risques d'une lutte trop systématique et provoqué ainsi une évolution généralisée vers des méthodes plus raisonnées, encouragée par la réglementation sur les contrôles de résidus mise en place dans les années 70. Ce n'est que vers la fin des années 80; sous la pression des mouvements d'opinion écologistes, qu'une politique environnementaliste a favorisé une prise de conscience généralisée, chez les agriculteurs, de la nécessité d'une évolution des méthodes de protection des cultures.

A la suite des taux de résidus observés dans les eaux, ces dernières années, une action fortement incitative a été mise en oeuvre depuis 1990 combinant un developpement des contrôles, une forte augmentation des taxes d'homologation des produits phytosanitaires, avec des opérations d'information et de sensibilisation de agriculteurs en faveur des méthodes de lutte intégrée. Les organisations professionnelles se montrent très coopératives pour cette politique qui se veut plus incitative que contraignante et les premiers résultats sont très encourageants. Par ailleurs la lutte biologique s'est assez largement développée dans les serres et sur certains organismes nuisibles tels que la pyrale du maïs avec des trichogrammes où l'emploi des souches hypovirulentes d'*Endothia parasitica* sur châtaignes.

Introduction

En matière de protection des végétaux l'objectif d'une politique est incontestablement la sécurité alimentaire non seulement sous l'aspect quantitatif de satisfaction des besoins alimentaires de la nation mais aussi, de plus en plus, par la recherche d'une qualité nutritionnelle complète et l'absence de risques sanitaires.

Années 40 : Mise en place des structures et des bases réglementaires - Avènement de la phytopharmacie moderne

Le service français de Protection des végétaux fête cette année son cinquantième anniversaire. La

[1]Politique: "Moyens mis en oeuvre dans certains domaines par le gouvernement - Exercice du pouvoir - Objectifs et moyens pour l'atteindre". Grand Larousse universel 1989.

création de ce service le 25 mars 1941 alors que l'Europe s'enfonçait dans la violence de la seconde guerre mondiale, est issue d'un projet élaboré en 1938 et fut confirmée par l'ordonnance du 2 novembre 1945.Cette origine est incontestablement un acte politique porté par l'espoir de paix. De plus, cette création se faisait par la fusion du service de l'inspection phytopathologique et des stations d'avertissement agricoles montrant ainsi une volonté d'action éducatrice, d'assistance technique à la production, avant que d'être contraignante et répressive. Cette orientation reste plus que jamais d'actualité. En matière de protection des plantes la politique découle à la fois de la politique agricole en général et de celle de la santé publique.

La décennie des années 40, dominée par le cataclysme de la guerre et l'effort de reconstruction qui l'a suivi, a cependant été marquée par l'avènement de la phytopharmacie moderne avec la découverte des propriétés insecticides du DDT et du HCH. Ouverture exceptionnelle vers l'avenir, qui succédait à 80 ans de maniement des pires poisons en agriculture : composés arsenicaux, nicotine, sulfure de carbone, strychnine, phosphure de zinc, etc ...! On frémit ! Mais on mesure l'importance du progrès accompli.

L'utilisation de ces poisons avait nécessité d'en réglementer, dès 1916, leur emploi et de créer en 1934 une commission d'étude de la toxicité des produits chimiques utilisés en agriculture. C'est sur ces bases qu'à l'instigation de Raucourt était promulguée en Novembre 1943 la loi d'homologation des produits antiparasitaires, fondée à la fois sur un contrôle de l'efficacité et une évaluation de la nocivité pour les utilisateurs aussi bien que les consommateurs des produits agricoles traités : hommes ou animaux. L'antériorité de cette loi par rapport au développement de la phytopharmacie a incontestablement limité en France les utilisations abusives de pesticides constatées dans d'autres pays.

Années 50 : L'espoir de la maîtrise des parasites des cultures

Les premiers insecticides organo-chlorés étaient rapidement suivis par les organo-phosphorés puis les premiers carbamates fongicides. Ces produits assuraient des perspectives toutes nouvelles pour la protection des cultures traditionnellement soumises à des traitements, c'est-à-dire la vigne, les arbres fruitiers et certaines plantes sarclées comme la pomme de terre ou la betterave.

L'évolution des cultures fruitières a marqué cette période par la constitution des premiers vergers commerciaux monospécifiques et la révélation de la pomme Golden. Dans ces années d'après guerre où l'on s'étonnait de ne plus manquer de tout, la politique agricole était résolument productiviste et l'efficacité des nouveaux produits phytosanitaires laissait croire à la possibilité d'une maîtrise absolue des parasites par l'application d'un programme de traitements systématiques. Les grandes cultures n'échappèrent pas à cette révolution. La découverte du 2,4D faisait entrer les applications phytosanitaires sur les vastes espaces consacrés aux céréales et le désherbage, en obligeant les agriculteurs à s'équiper en matériel de pulvérisation, ouvrait la voie aux fongicides et aux insecticides, ainsi qu'aux régulateurs de croissance favorisant eux-mêmes l'emploi d'engrais azotés.

Cependant dans ce climat de béatitude, un groupe de chercheurs créait l'O.I.L.B en 1956. Et le 1er janvier 1958 le traité de Rome, créant la Communauté Economique Européenne, entrait en vigueur.

Années 60 : Une politique de développement dominée par les normes de mécanisation

C'est bien la mise en oeuvre de la Politique Agricole Commune qui va marquer l'évolution de l'agriculture dans les années 60 en ouvrant le marché de l'Europe aux productions agricoles françaises mais aussi en développant la concurrence entre les productions nationales. Pour la protection des plantes le secteur des fruits et légumes en est la meilleure illustration.

C'est tout d'abord l'application des directives communautaires sur la normalisation obligatoire qui va institutionnaliser la notion de qualité commerciale fondée sur des critères d'aspect : calibre - coloration - absence de défauts épidermiques. Ainsi à la politique productiviste quantitative des années 50 va s'ajouter la recherche d'une qualité commerciale supérieure qui néglige totalement les qualités intrinsèques du produit. L'effet de levier du classement selon les catégories de commercialisation, Extra - I ou II, est très fort sur les prix, avec des écarts atteignant 20 % entre deux catégories et 15 % entre deux calibres successifs.

Le risque parasitaire n'est plus seulement quantitatif par réduction du volume de la récolte, il devient qualitatif, des attaques mal maîtrisées pouvant entraîner une perte de revenu considérable par déclassement de catégorie. La tendance des producteurs à une protection phytosanitaire systématique, amorcée dans la décennie précédente, va s'en trouver renforcée d'autant que la panoplie des substances actives s'est considérablement élargie et l'équipement mécanique des exploitations conduit à une adaptation des techniques agricoles aux normes de la mécanisation. La politique agricole française sera marquée en 1965 par la mise en place des organes de la compétitivité commerciale sur le marché européen : les groupements de producteurs et les comités économiques agricoles. Animés à l'origine par une logique exclusivement commerciale ces organismes visaient une discipline collective de mise en marché destinée à régulariser les apports et à éliminer les produits hors normes.

La protection sanitaire entrait dans cette stratégie pour rechercher l'obtention de rendements réguliers à un niveau élevé et une proportion importante de produits commercialisables en Extra ou I. Pour un coût de l'ordre de 3 % du coût final des produits au moment de leur mise en marché, la protection sanitaire n'apparaissait pas coûteuse par rapport au risque de voir le produit brut dévalué de 25 à 30 % en cumulant les effets quantitatifs et qualitatifs d'une attaque parasitaire mal maîtrisée. C'est dans ce contexte que le ministère de l'agriculture décidait cependant en 1967 d'encourager les premiers essais de lutte intégrée en vergers. Quelques événements biologiques inquiétants étaient venus bouleverser la belle euphorie des années 50. Les pullulations d'acariens dans les vergers par destruction de l'entomofaune ou la résistance envers les organo-phosphorés développée par le puceron vert du pêcher (*Myzus persicae*) ou le psylle du poirier (*Psylla piri*) en sont les exemples les plus spectaculaires.

L'appel d'Ovronaz lancé par L'OILB, marque le début d'une prise de conscience des risques d'une protection chimique systématique et aveugle et définit les bases d'une conception plus écologique de la protection phytosanitaire. Les essais réussis de lutte biologique contre certaines cochenilles et notamment en France l'utilisation de *Prospaltella perniciosi* sur le Pou de San José (*Quadraspidiotus perniciosus*) ont montré la voie. Mais si quelques opérations expérimentales étaient ainsi encouragées officiellement, la politique globalement suivie tant par les organismes administratifs que par les professionnels ou les industriels de la chimie restait résolument en faveur des traitements dits "d'assurance".

Années 70 : Une réglementation renforcée sur les études toxicologiques et la mise en place des contrôles de résidus.

La politique agricole commune a porté ses fruits, les premières crises de surproduction apparaissent et, en réponse à la compétition commerciale qui s'accroît, l'agriculture entre dans la voie de l'intensification et de la spécialisation. On en oublie les principes agronomiques de base : pourquoi ne pas cultiver blé sur blé ou maïs sur maïs ? Parasites et maladies sont heureux, trouvant toujours à leur portée leur plante préférée! Qu'à cela ne tienne, le pulvérisateur utilisé pour les herbicides va pouvoir épandre des fongicides et des insecticides. L'agriculture change de visage. Peut être change-t-elle aussi d'âme en tournant le dos à la biologie.

D'un point de vue écologique l'effet est considérable, en passant des cultures pérennes (vignes et vergers) qui couvrent moins de 5 % de la surface agricole utile aux grandes cultures, l'usage des produits de protection des cultures va progressivement gagner plus de la moitié de cette surface. L'impact sur le milieu naturel va se généraliser. La prise de conscience de ce risque, une meilleure connaissance des effets cumulatifs sur la chaîne alimentaire vont provoquer le renversement des idoles des années 50: DDT, HCH et d'autres organo-chlorés sont interdits.

Précisément, dans les vergers, qui ont 15 ans d'expérience d'une lutte chimique intensive, les difficultés se multiplient et l'idée d'un raisonnement biologique de la protection sanitaire ébranle la certitude de la protection systématique. Entre temps les premiers essais de lutte intégrée ont montré qu'il était possible de réduire le coût de la protection sanitaire de 25 à 30 % sans aucune perte d'efficacité. Bien au contraire l'équilibre biologique restauré permet de nouvelles économies sur les acaricides. Cependant les adeptes de la lutte intégrée restent peu nombreux et, à la fin des années 70, on ne dénombrera que 3000 ha de vergers où elle est appliquée.

Malgré les stages pratiques de formation organisés par l'Association de Coordination Technique Agricole (A.C.T.A.), la masse des arboriculteurs reste réticente vis à vis des observations ; manque de formation biologique, manque de temps à y consacrer et aussi toujours la crainte de la perte de revenu sont autant de freins. De son côté l'O.I.L.B crée en 1978 un comité international pour la valorisation de la lutte intégrée qui s'appuie sur des comités nationaux comme le GALTI en Suisse ou le COVAPI en France. Ce comité avait pour objet de permettre la délivrance d'un label OILB à des fruits ou légumes obtenus selon les principes de la production intégrée. C'est à cette occasion qu'à été défini le concept de production intégrée ayant pour objectif, non seulement l'application de la lutte intégrée, mais l'équilibre de la physiologie et de la santé des végétaux pour l'obtention de produits à la fois sains et de bonnes qualités nutritionnelles et gustatives.

En France l'initiative du COPAVI n'a pas obtenu auprès des autorités au cours de cette période, un soutien très actif et les professionnels, aussi bien de la production que de la commercialisation, ont montré surtout de l'indifférence ou du scepticisme, en dehors de quelques-uns qui ont su prévoir l'évolution actuelle. Mais à l'extrémité de la chaine de commercialisation les consommateurs en manifestant leur inquiétude pour la présence de résidus de produits chimiques sur les aliments obligèrent les gouvernements à adopter une réglementation sur les taux de résidus, reprise au niveau communautaire. Dans ce contexte la stratégie des firmes chimiques va évoluer par une accentuation de l'innovation : mise au point des premiers pyréthrinoïdes et des fongicides systémiques, ainsi que par une diversification de la gamme des produits commercialisés. La politique officielle au cours de cette décennie s'est donc surtout traduite par un renforcement de la réglementation d'une part sur les exigences toxicologiques en vue de l'homologation d'autre part en fixant des limites de tolérance pour les résidus.

Années 80: Emergence d'une politique environnementaliste et d'une prise de conscience collective.

Avec un certain retard sur d'autres pays européens, la France va progressivement être gagnée au début des années 80 par les préoccupations écologistes d'une proportion croissante de la population. La pression politique environnementaliste s'accentue ainsi un peu plus à chaque scrutin national en même temps qu'au sein de la Commission des Communautés Européennes à Bruxelles. C'est ainsi que, dès le début des années 80, les producteurs adeptes de l'agriculture biologique se voient reconnaître le droit de certifier leurs produits sous cette appellation, précédant de 10 ans la décision communautaire sur ce même sujet.

Il se crée un mouvement d'opinion qui va s'étendre à l'ensemble des acteurs économiques sans que l'Etat intervienne autrement que par un renforcement progressif des contrôles toxicologiques pour l'homologation ou sur les contaminants alimentaires. Les firmes phytosanitaires, les premières, ont adopté après les avoir combattus auparavant, les principes de la lutte intégrée autant sous la pression de l'opinion que devant la généralisation des résistances développées par les organismes nuisibles qui engendrent une obsolescence accélérée des nouvelles molécules.

Dés le début des années 80 les services français de Protection des végétaux ont également fait des principes de la lutte intégrée le fondement de leurs préconisations notamment dans les avertissements agricoles. La réponse des producteurs à l'effort de diversification et de précision des conseils délivrés par les bulletins d'avertissements agricoles est aisément mesurable par la progression du nombre des abonnés passés de 20 000 à 67 000 au cours de ces dix années. Cependant la lutte intégrée au sens strict n'a pas beaucoup progressé, toujours freinée par les difficultés pour appliquer les observations préalables sur chaque parcelle. Mais son effet d'entraînement, par la démonstration de son efficacité liée au progrès dans la mise au point de nouvelles molécules plus spécifiques beaucoup moins toxiques, a été considérable au point que la marge de progrès qui la sépare des méthodes généralement appliquées n'est plus ce qu'elle était au cours des années 60. Chimistes et biologistes se rapprochent ainsi autour du concept de lutte raisonnée.

Cette décennie a aussi été marquée par la réussite de certaines applications très ciblées de lutte biologique :

- la protection des cultures sous serres tout d'abord notamment avec *Encarsia formosa,*
- la mise au point de l'homologation de spécialités à base de *Trichoderma viridae*
- l'utilisation, sur plusieurs milliers d'hectares de maïs, de trichogrammes pour lutter contre la pyrale,
- l'extension après des débuts un peu lents de l'emploi du *Bacillus thuringiensis* à de nombreuses cultures, ainsi qu'en forêts et pour la limitation des populations de moustiques,
- la conduite pendant ces dix années d'un vaste programme de diffusion de souches hypovirulentes *d'Endothia parasitica* sur les chataîgniers.

Années 90 : Développement d'une politique environnementaliste surtout incitative.

En ce début des années 90 c'est par l'eau que nous arrive l'infléchissement politique majeur en matière de protection des plantes. En constatant que les eaux de tous les pays de la communauté ne respectaient pas les exigences des directives communautaires de 1975 et 1980, les autorités politiques prennent conscience des problèmes liés aux méthodes de protection des cultures. On remarquera que, au cours de cette période de cinquante années l'intervention du pouvoir politique ne s'est manifestée par voie réglementaire que : soit préventivement par une loi d'homologation promulguée très précocement et progressivement renforcée avec le développement de la phytopharmacie, soit par une obligation de résultat faite aux agriculteurs en fixant les tolérances de résidus sur les produits alimentaires.

Mais en donnant, il y a cinquante ans, la compétence à un service d'Etat de protection des végétaux sur l'ensemble des aspects réglementaires et techniques de la préservation de la santé des plantes, les autorités de l'époque ont permis d'accompagner l'évolution de l'agriculture d'un effort d'adaptation des techniques de protection. Cet outil technique, entièrement rénové et modernisé au cours des années 80, constitue un moyen d'intervention, en faveur d'une protection des cultures plus respectueuse de l'environnement, d'autant plus efficace qu'une longue tradition de conseils lui a donné la confiance des agriculteurs. En disposant de pouvoirs réglementaires aussi bien pour l'homologation des produits phytosanitaires que pour l'organisation des prophylaxies collectives et les contrôles à l'exportation il peut appliquer une politique surtout incitative en direction des agriculteurs.

Ceci s'est traduit en 1991 par un certain nombre d'actions qui montrent un infléchissement politique et qui ont pu être entreprises sans qu'il soit nécessaire de modifier les dispositions législatives de base existants depuis longtemps :

- une aggravation des taxes d'homologation des produits phytosanitaires permettant de participer financièrement à un réseau de surveillance des contaminants dans les eaux et dans l'environnement ;
- un doublement des crédits d'intervention pour les prophylaxies collectives permettant la mise en oeuvre d'un programme de développement des méthodes de protection intégrée des cultures ;
- une aide accrue à la production à l'échelle industrielle d'auxiliaires utilisés en lutte biologique ;
- la mise au point de méthodes de prévision des transformations subies par les résidus de produits phytosanitaires dans les processus de fabrication appliqués par les industries agro-alimentaires ;
- le développement des études de modélisation et de prévision des risques d'attaques parasitaires des cultures.

Parallèlement, les professionnels aussi bien de la production que de l'agro-fourniture ont adopté des chartes pour une agriculture plus respectueuse de l'environnement et par conséquent une modération des fumures et un développement de systèmes de protection raisonnée. Les Tableaux 1 et 2 joints en annexe donnent l'estimation que l'on peut faire actuellement des surfaces de cultures soumises à de véritables systèmes de lutte intégrée et d'autres part de celles recevant des applications de lutte biologique.

Conclusion

A la lecture de ces chiffres on remarquera que la lutte intégrée proprement dite aura peu progressé en France au cours des 20 dernières années. Est-ce un échec ? Oui si l'on raisonne uniquement en termes statistiques. Non si l'on mesure les progrès qualitatifs accomplis. Les précurseurs de la lutte intégrée ont su démontrer la possibilité d'une maîtrise intelligente de l'état sanitaire des plantes, ils ont constitué une référence permanente face aux écueils de la protection systématique. leur témoignage a lentement mais régulièrement facilité une prise de conscience généralisée des risques d'une lutte aveugle et aidé à la conception d'une lutte raisonnée qui a adopté le langage et certaines des méthodes de la lutte intégrée, préparant ainsi d'autres évolutions.

Mais cette lenteur montre aussi combien les contraintes économiques, le poids des habitudes et l'opinion publique en général s'opposent, même en protection des plantes, à toute évolution trop rapide. C'est cet environnement socio-économique qui est en train de changer et qui crée les conditions favorables à une nouvelle étape à laquelle les progrès accomplis dans la recherche en biochimie cellulaire vont participer très fortement.

Dans le domaine scientifique le changement est très profond et les nouvelles substances actives mises sur le marché répondent à des exigences d'écotoxicité ignorées il y a 25 ans. De plus ces nouveaux produits s'utilisent désormais à des doses calculées en grammes par ha alors que l'on comptait en centaines, voire en kilogramme, avec les produits plus anciens.

Dans le domaine réglementaire la directive communautaire adoptée en juillet 1991 instaure des conditions harmonisées d'autorisation de mise en marché des produits de protection des plantes. Elle prévoit notamment, dans un délai de 12 ans, la révision obligatoire de toutes les autorisations déjà accordées dans les Etats-membres. Une proportion importante des quelques 500 matières actives actuellement employées en Europe ne recevront certainement pas d'autorisation renouvelée; soit qu'elle ne satisfont pas aux critères écotoxicologiques fixés par la directive soit que, leur ancienneté ne leur permettant pas de bénéficier d'une protection par des brevets industriels, elles ne trouvent pas de société acceptant d'investir dans l'établissement d'un dossier répondant aux exigences de la directive. Ainsi les objectifs de réduction globale des quantités de pesticides utilisés et de diminution du nombre des matières actives autorisées, affichés récemment par certains de nos partenaires européens, correspondent tout à fait à l'évolution résultant des effets cumulés du progrès scientifique et de la réglementation communautaire.

En vingt cinq ans tout est changé, mais les idées émises par les auteurs de l'appel d'Ovronaz demeurent de la plus vivante actualité et nous devons les remercier de leur clairvoyance.

Annexe

Tableau 1. Estimation des superficies en lutte intégrée, France 1990/91. Source MAF/SDPV

Arboriculture fruitière		4 600 ha (2,8 %)
dont:	Pommier	3 300 ha
	Poirier	850 ha
	Pêcher	300 ha
Vigne		500 ha
Cultures légumières		
dont:	Plein air	(n.d.)
	Serres	1 500 ha (28 %)

Tableau 2. Estimation des Superficies recevant une lutte biologique France 1990/91 - Source MAF/SDPV

Cultures légumières		
	Serre	821 ha
dont:		
	Tomate	706 ha (86 %)
	Concombres	91 ha (11 %)
Cultures fruitières		
	Châtaignier *(Endothia parasitica)*	1 300 ha (10 %)
Maïs		
	Trichogramme	8 000 ha (0,5 %)
Agriculture biologique		
	Toutes cultures	60 000 ha (0,2 %)

Plant protection policy in the Federal Republic of Germany

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Summary

The Germany plant protection policy is characterized by increasing awareness of environmental impacts since the end of the sixties. This is expressed in the Plant Protection Act of 1968 and to a larger extent in the new Plant Protection Act of 1986.

The basic principle of the new plant protection policy in Germany is to keep a balance between the agricultural purpose of plant protection on the one hand, and the possibly adverse or even unacceptable side-effects of plant protection measures on the other. Besides regulations concerning the registration of pesticides, provisions exist as to the use of specific plant protection products. These regulations include both general rules and prohibitions and specific rules with regard to specific compounds.

Integrated plant protection is a recognized and legal term in the Plant Protection Act and a major focal point; in principle, priority is given to non-chemical treatments. Implementation of integrated plant protection is financially supported by different sources. New regulations are being prepared including the implementation of expected new EC regulations.

Introduction

The first regulations in plant protection in Germany were established around the beginning of this century. They concerned mainly the proper execution of control measures. The next memorable action was the establishment of the Plant Protection Service (Pflanzenschutzamt). This took place some 40 years ago and was completed at the end of World War II.

During this period the major area of attention of plant protection legislation was the formulation of phytosanitary regulations, for example to reduce the losses caused by the Colorado potato beetle, in order to inhibit any further spread of harmful organisms and to develop possibilities for efficient control methods.

It is generally known that in the fifties and the sixties the use of pesticides, as well as their production, increased rapidly. At the same time voices warning of the adverse side-effects of chemical pesticides on human beings, animals and the environment became increasingly louder.

The Plant Protection Act

The first political reaction to these problems was to launch the Plant Protection Act in 1968 which regulated the registration of plant protection products. The leading principle of this act was to keep a good balance between effective and reliable plant protection whilst minimizing as much as possible the adverse side-effects for man, animals and environment.

But the registration comprised only the permission for pesticides to become commercialized, and the supervision of the labelling of these products to inform farmers in the best possible way. The label of the plant protection product did not bind the user legally, but the latter was obliged to meet all the existing requirements, such as the maximum residue level (MRL), the protection of water etc. In consequence of this legal structure the Minister of Food, Agriculture and Forestry had the authority to ban totally, or restrict the use of, certain pesticides if this turned out to be necessary when adverse side-effects were recorded.

Three years later the first regulation (the "Pflanzenschutz-Anwendungsverordnung") was published in the official gazette (Bundesgesetzblatt). In this regulation several chlorinated hydrocarbons were banned to stop in the first place the accumulation of these compounds in mother's milk. The banning of DDT followed one year later by means of a special act. After this the regulation was amended several times as a result of newly acquired scientific insights. In 1980 the prohibition of the use of mercury was included. A totally new version of the regulation was published in 1986. Because of the increasing necessity to protect water catchment areas from contamination by pesticides, another new version was launched in 1988, including restricted use for 79 active compounds. The last amendment of the regulation was made in spring 1991 to ban the use of atrazine. In this regulation the implementation of the EC-Directive 79/117 (the "Prohibition Directive") has also been taken into account.

Integrated plant protection

Parallel to these developments in plant protection legislation a broad fundamental discussion took place on the future direction of plant protection. Already in the mid-seventies specialists were convinced that the only realistic chance for healthy and responsible plant protection in the future could be found in the concept of "Integrated Plant Protection".

The main reasons for this conclusion were:

1. Increasing problems with resistance of target organisms
2. Elimination of beneficial organisms
3. Increasing problems with pollution of the environment
4. Increasing costs of pesticides
5. Total dependency on the pesticide industry

Another important potential reason, namely the health hazards for man and animals, could be removed from the list, because in Germany this problem has been dealt with effectively by the setting up of a unit of toxiological experts.

In the early eighties the debate between agricultural and environmental specialists lead to the inclusion of environmental objectives in the plant protection legislation. A major consequence of this discussion was that the Federal Ministry of Agriculture launched a programme to stimulate the implementation of integrated plant protection into practice as much as possible.

This programme focused on the following points:

a) Amendments of the Plant Protection Act, for example:
   - stricter rules in the use of pesticides,
   - prohibition of the use of pesticides in areas not in use for agriculture or forestry,
   - prohibition of the use of pesticides in water or in its immediate vicinity,
   - prohibition of the use of pesticides on farms without license,
   - stricter regulations for the registration of pesticides,
   - instruction to the authority in plant protection regulations, the Federal Biological Research Centre (Biologische Bundesanstalt), to collaborate with the Federal Environmental Agency (Umweltbundesamt) in all matters concerning the registration of pesticides.
   - stricter regulations for spraying equipment.

b) Strict supervision of the quality standards of pesticides

c) Stimulation of research on integrated plant protection and resistance problems

d) Promotion of education and training in integrated plant protection methods
e) Reinforcement of the Extension Service

Achievements

The following points summarize what has been achieved in the past 10 years.

1) The design of an updated Plant Protection Act has been completed and published in 1986. It covers all considerations mentioned above and attaches the highest priority to the protection of the environment. The term "Integrated Plant Protection" has been legalized and introduced into the Act and is described as follows: "Integrated plant protection is a combination of plant protection measures, with primary attention being paid to biological, biotechnical, plant-breeding and cultural methods and with minimal use of chemical pesticides". This means an outspoken preference for non-chemical plant protection measures and the acceptance of the principles of integrated plant protection in agricultural practice. It means also that priority must be given to the education of farmers to make them familiar with the methods of integrated plant protection.
2) The stricter rules for the registration of plant protection products have cut back drastically the number of permitted products as well as the number of active compounds. To the already existing requirements regulations have been added with regard to a more precise evaluation of the possible impact of pesticides on soil, surface water, ground water, air and beneficial organisms. Product properties, such as leaking, volatilization or bioaccumulation, are important in this evaluation process.
   At this time there are approximately 900 plant protection products on the market in Germany (in 1986 ca. 1,800!), and approximately 200 active compounds (in 1986 ca. 300!). It should be noted that many of these products have been taken out of the market for economical, rather than environmental reasons, since industry was not prepared to invest extra costs to produce new data to meet the sharper requirements for registration.
   Sometimes environmentalists consider this to be an advantage. But from the viewpoint of integrated plant protection the cut back in pesticides has reached the limits of reasonableness. In specific cases selective pesticides are no longer available, which forces farmers to use products with broad-spectrum action. So, it also becomes an undesirable development from the environmental point of view!
3) Much research in integrated plant protection has been done not only at the Federal level, but also at the State (Länder) level, and last but not least by the industry. This is still in progress. The major results so far obtained are:
   a) progress has been made with the study of specific components of integrated plant protection, such as the development of economic thresholds and of biocontrol methods against specific pests and diseases,
   b) some companies have been established, with financial support, to produce beneficial organisms, in particular for the protection of glasshouse crops,
   c) studies on economic feasibility have been made to answer the question to what extent the restricted use of pesticides is acceptable before it threatens a farmer's income.

However, there are also aims which have not been achieved so far:

   d) development of complete integrated plant protection systems,
   e) enlargement of the staff of the Extension Service to meet the necessary requirements,
   f) change of the quality standards of agricultural products within the EC-context, so that fewer pesticides can be used,

g) change of the price policy in the EC. The existing price system is responsible for some very unfavourable developments in agricultural production, such as reduced crop rotation and increased use of fungicides,

h) maintenance of a balance between the process of limiting the use of pesticides through stricter regulations, and the development of biological and/or biotechnical methods which can replace chemical methods.

Points d) to h) illustrate that although it was recognized in Germany quite early that drastic changes in plant protection policy were necessary, and that the conditions for changes were favourable, much persistence was and is needed to bring these changes about.

Some remarks on recent developments

Better protection of agricultural workers, consumers and the environment is a major issue of the new policy. However, not all demands for change can be realized immediately, e.g., to register pesticides only when these are really necessary for a responsible plant protection. But who decides what is really necessary? Necessary now or in the future? And which government wants to start a ten-year programme together with the industry to develop new plant protection products without being accused of a dirigistic policy?

All in all we are convinced that in Germany a good and progressive line has been followed, with perhaps a little too much concern for the competitive ability of our farmers. The latter aspect was one of the reasons that our country has strongly and successfully supported the proposals made by the EC-Commission to harmonize the registration of pesticides within the EC. After many amendments an EC-Directive has recently been accepted as a compromise. So it is certain that the other member countries in the EC must follow the developments in plant protection policy that have already taken place in Germany, in which more attention is given to the protection of the environment.

It is also worth mentioning that in our country the discussion about the implementation of EC Directive 91/414 has been started already. In this context the following changes and amendments of the Plant Protection Act are under discussion:

a) formulation of the principles of integrated plant protection (see Table 1),

b) limitation of the accessibility to specific products (farmers must present a prescription),

c) further measures to reduce the use of pesticides.

Table 1. Principles of integrated plant protection

* to develop cultivation systems with the lowest possible number of noxious organisms;
* to promote plant health by cultural measures such as crop rotation; soil tillage, resistant crop varieties, sowing planting times, moderate fertilization;
* to watch the growth of the crop, the occurrence and the distribution of noxious organisms in the crop;
* to use mechanical, biotechnical and biological plant protection measures as much as possible;
* to use pesticides only if damage thresholds will be exceeded;
* to use selective pesticides preferentially;
* to intensify education and involve the Extension Service as much as possible.

Several European countries have put an extra tax on pesticides, and have developed plans to reduce the use of pesticides to a precisely specified level, in a precisely determined period. In Germany we do not favour this approach, because we believe that a tax cannot be given in circumstances with conflicting interests, as prevail in the case of plant protection products. A certain product can, for example, meet all requirements with regard to human health but not to the protection of the environment. It is also difficult to meet all environmental criteria, e.g. protection of beneficial organisms versus leaking, lower persistence versus bioaccumulation.
So we prefer to stick to reducing the volume of pesticide use wherever possible. In addition, we try to stimulate strongly research on non-chemical plant protection measures, on which topic a special research programme will soon come into effect.

Some concluding remarks

1) Legal provisions for a new plant protection policy have been made by updating the Plant Protection Act of 1986. Priority is given to non-chemical plant protection measures and the necessary environmental considerations have been included.
2) Recent developments have shown that high demands for the registration of pesticides can lead to a limited availability of certain products. This can on its turn threaten the aims of integrated plant protection.
3) If priority is given to non-chemical plant protection measures, a careful balance must be kept between the banning of chemical products and the availability of biological and biotechnical methods. It means an intensification of research and an enlargement of the Extension Service.
4) Major aims to keep good pesticides for the future are to restrict the use of these products whenever possible, and to stop the transport of these products or their metabolites into other compartments of the environment.
5) Shifting the current plant protection to a more environmentally friendly system needs much perseverance and the ability to carefully distinguish between realistic ideas and idealistic motives.

Documentation

For those who are interested in more details of the recent crop protection legislation in Germany the following documentation is obtainable from the Federal Ministry of Food, Agriculture and Forestry (see list of participants for full address).

Gesetz zum Schutz der Kulturpflanzen (Pflanzenschutzgesetz - PflSchG)) vom 15. September 1986 (BGBl. I S. 1505), zuletzt geändert durch das Dritte Rechtsbereinigungsgesetz vom 28. Juni 1990 (BGBl. I S. 1221).

Verordnung zum Schutz der Bienen vor Gefahren durch Pflanzenschutzmittel (Bienenschutzverordnung) vom 19. Dezember 1972 (BGBl. I S. 2515).

Verordnung über Pflanzenschutzmittel und Pflanzenschutzgeräte Pflanzenschutzmittelverordnung) vom 28. Juli 1987 (BGBl. I S. 1754).

Verordnung über Kosten der Biologischen Bundesanstalt für Land- und Forstwirtschaft (BBA-KostV) vom 1. September 1981 (BGBl.I S.901).

Pflanzenschutz-Sachkundeverordnung vom 28. Juli 1987 (BGBl. I S. 1752).

Verordnung über Anwendungsverbote für Pflanzenschutzmittel (Pflanzenschutz-Anwendungsverordnung) vom 27. Juli 1988 (BGBl. I S. 1196), geändert durch die erste Verordnung zur Änderung der Pflanzenschutz-Anwendungsverordnung vom 22. März 1991 (BGBl. I S. 796).

Extension Section

Changing extension in crop protection in various crops and regions

IPM in Italy with particular reference to the Emilia-Romagna region

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Summary

Integrated pest management (IPM) came into field use in Italy about 10 years ago, thereafter increasing slowly but continuously. At present, several large-scale programmes are underway, of which those in the Alto Adige/Südtirol and Emilia-Romagna are the oldest and the biggest. Recently, the Ministry of Agriculture has set up a big project to improve scientific understanding and promote the use of IPM throughout the country.

The Emilia-Romagna programme involves about 4500 farms, i.e. 10 000 hectares of orchards (apple, pear, peach, plum, apricot, cherry) and vineyards. Recently arable crops, both in the open field and in protected culture, were included. The extension work is done by about 150 officers, employed by cooperative organizations and the grower associations, with a fiancial contribution of the regional government, while another 40 are handling the experimental work, under the supervision of several research institutes.

Several non-chemical control methods are applied, such as *Bacillus thuringiensis* for leafrollers, mass trapping with sex pheromones for the goat moth, prevention of spider mite outbreaks by carefully chosing the chemicals to apply against other pests. Forecasting models are used to rationalize the control measures.

The results can be summarized in a 30-40% reduction of the number of chemical treatments and - even more important - in an evolution of the plant protection philosophy at the farm level. The main disadvantage is the high cost of this programme. The regional government wants to increase the number of participating farmers, a policy that will involve a radical change in the projects'general organization.

IPM in Italy

About 25 years ago the staff of the Institute of Entomology of the University of Bologna realized the increasing need to rationalize plant protection and, particularly, orchard protection. At that time some 15-18 treatments a year with insecticides and acaricides were a common practice in apple orchards. The use of chemicals was ever increasing. Technical advice to farmers was given mainly by the chemical companies, and very few people took into account the environmental problems and the amount of pesticide residues in fruits.

A research group headed by Prof. Maria M. Principi was set up and field experiments were carried out for five years. We followed the guidelines of the IOBC/WPRS Working Group "Integrated Control in Orchards", but had to define sampling methods and economic thresholds for some typically Italian pests (leafminers, leafrollers etc.) and to adapt the control measures to the Italian environment. After five years, we felt we were ready for field application. The plant protection manager of the regional government, Enrico Pucci, agreed about the need for a change in plant protection philosophy. A fruitful collaboration was established between the Institute of Entomology of the University and the Regional Plant Protection Service, and the first Italian integrated control programme was put into practice. More details about this programme will be given further on.

Since then, much work has been done. A working group for integrated control of the National Research Council was set up, but it lacked coordination as the environmental conditions and the main crops greatly differ region to region. Recently, the Ministry of Agriculture has funded a big programme for biological and integrated plant protection that involves both research and field application projects (see Imbroglini, this volume). It has given rise to several initiatives undertaken by regional governments (in Italy agriculture lies within the jurisdiction of regional administrations, the national Ministry of Agriculture having only coordinating functions) and has provided some oxygen to research institutions working on integrated and biological plant protection. I should also mention that European Community funds for technical education are widely used to finance integrated control courses.

Today integrated plant protection programmes big enough to influence the attitudes of farmers have been established in several Italian regions: Piemonte, Trentino-Alto Adige (Südtirol), Veneto, Emilia-Romagna, Umbria, Lazio, Sicilia (Fig. 1). Apple, pear, peach, plum, apricot, cherry, olive, grape, protected cultures and ornamental plants are involved. The oldest and biggest are those of Alto Adige/Südtirol (a bilingual, Italian and German area) and Emilia-Romagna. They are somewhat different: in Emilia-Romagna a lot of sampling work is done and farmers are often visited by extension officers, while in the Alto Adige, where the number of participating farms is higher, technical bulletins and meetings are used.

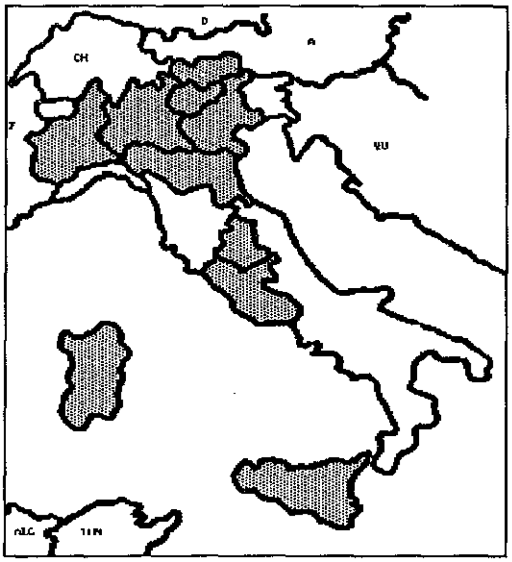

Figure 1. - Shaded areas: regions of Italy where significant IPM programmes are applied.

The Emila-Romagna programme

General organization

The integrated control programme of the Emilia-Romagna region covers more than 20,000 hectares and 4500 farms (Fig. 2). This means 19.4% of the orchards, 7.4% of the vineyards, 13.8% altogether. Apple, pear, peach, plum, apricot, cherry and grape cultures have been involved for several years (Tab. 1); sugar-beet, industrial tomato and strawberry began to be involved in 1991; some other 20 herbaceous crops are still at the experimental level.

Table 1. Number of orchards and areas (hectares) covered by the Emilia-Romagna integrated pest management programme.

Crop	Apple	Pear	Peach	Plum	Apricot	Cherry	Grape	Total
Plots	1726	1840	3000	327	303	133	1842	9171
Area	2354	4733	6876	398	265	120	4969	19715

As to general organization, Italy is a special case. Universities have no extension service; there are rather few experimental stations for agriculture and most of them belong to the Ministry of Agriculture, while regional governments manage the extension service. In such conditions a programme that requires both a research and an extension effort can only be carried out in close collaboration between universities and regional extension services. Fortunately, in our case this collaboration has yielded good results. Briefly, the regional administration funds the research work done by universities and other institutions, which also define the technical guidelines and collaborate in all scientific matters. At the end of each year meetings are held at which researchers and extension officers discuss the results and define the research programmes for the following year. Some officers (40 altogether) help the scientific advisers in the experimental work as well as in the technical tasks (meetings, analysis of results, support of extension officers etc.). Of course, the level of research work varies but, generally speaking, it is quite adequate to the needs.

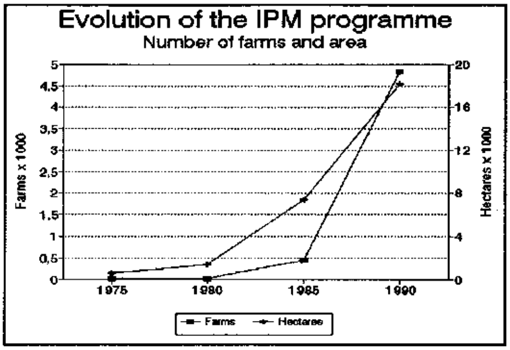

Figure 2.- Size of the Emilia-Romagna IPM programme.

One hundred fifty-three extension officers (Fig. 3) provide the farmers with technical advice (roughly an extension officer has to take care of 30 farms). They are employed by the farmers' associations (both cooperative and professional organizations), with a contribution from the regional government. This contribution varies in time: it is high at the beginning, but decreases every year. The underlying philosophy is that the farmers' organizations receive help for new extension officers who are learning their job, but ultimately they have to pay the salary to their personnel.

The extension officers must hold a master's degree or a high school diploma (5 years from 14 to 18) in agriculture. They have to attend a 1-year full-time course in IPM, held by the scientific advisers and other specialists, including a summer period at the farmers' organizations. Their training also includes the assistance of a senior colleague, during the first year of field work.

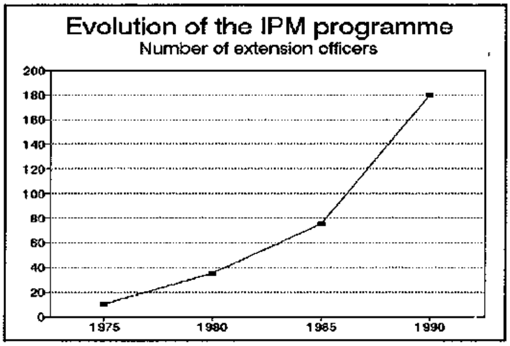

Figure 3.- Number of extension officers in the Emilia-Romagna IPM programme.

The farmers on the other hand have to attend short courses given by the extension officers. They are periodically visited by the extension officers who give them advice, thereby continuously improving their education and training.

The farms are divided into two categories: some are strictly followed by the extension officers, who visit them every week, regularly sample the most important pests and diseases and give advice about the control measures; the others are left under the responsibility of the farmer, who calls the extension officer only when he feels uncertain about what to do. In any case he has to justify every treatment with the results of sampling, according to the general guidelines. The first ones must be considered as the examples to be followed by all the other farmers.

Printed and phone bulletins, updated weekly, help the farmers to reach the best decisions. Every year a booklet is published, with colour pictures of pests and diseases, technical guidelines, sampling methods, a list of allowed chemicals and their side-effects, information on parasites and predators etc.

Some special laboratories were also created, namely:

- spray equipment testing lab;
- forecasting models lab;
- computer network;
- insectary for mass production of auxiliary insects.

Results

The reduction of chemical control was achieved both by rationalizing the use of pesticides, in some cases with the help of forecasting models, and by developing alternative control methods. At present the following non-chemical techniques are widely used in the field:

Method	Pest
Mating disruption with pheromones	Oriental fruit moth; goat moth
Bacillus thuringiensis	Leafrollers; grape moth
Prevention Red spider mite	
Washing treatments with wetting agents	Pear psylla
Chrysoperla carnea (*)	Strawberry aphids
Phytoseiulus persimilis (*)	Spider mites

(*) Release of mass-reared insects or mites in protected cultures.

In 1990 the overall reduction in the number of chemical treatments was 25%. This can be considered a good result, although in the first years it reached almost 50%, without sacrificing the quality of the product. At that time, only insect control was taken into account: it is easier to reduce the use of insecticides. With fungicides the job is not so easy. Furthermore, the farmers have learnt a lot from the IPM programme. Even those that did not take part in it were able to reduce the use of chemicals. Therefore the advantages of IPM became less evident, but we consider this change in plant protection philosophy a great side-effect of our programme: perhaps the most important result. Moreover, today the number of extension officers who belong to public agencies is greater than the number of who belong to the chemical companies. This is another important achievement. The chemical companies are doing a good job but, of course, their aim is selling as many pesticides as they can.

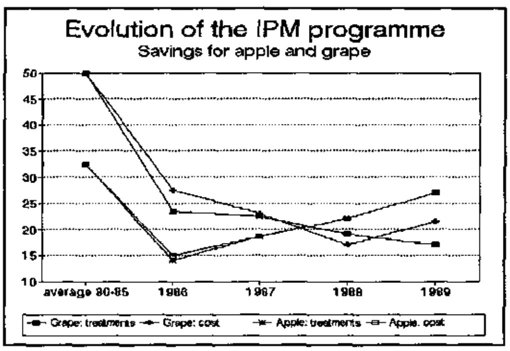

Figure 4.- Percent savings obtained with IPM, expressed both as number of chemical treatments and cost, for apple and grape.

In Fig. 4 summary of the savings obtained with IPM in two typical examples, apple and grape, is given. In Table 2 we list the costs defrayed by the regional government and give an example of the budget for pome fruits.

Table 2. Budget of the Emilia-Romagna IPM programme

A. Annual costs of IPM programme		
A1. Overall costs		
	- Research	Lit. 2,400,000,000 ≈ US$ 2,000,000
	- Extension service	Lit. 3,600,000,000 ≈ US$ 3,000,000
	- Total	Lit. 6,000,000,000 ≈ US$ 5,000,000
A2. Costs per hectare of extension service		
*	- 3,600,000,000 : 20,000,000 = Lit. 180,000 ≈ US$ 144.5	
B. An example: pome fruits and 20% savings (costs per hectare)		
	- Costs of traditional protection	Lit. 2,000,000 ≈ US$ 1500
	- 20% of 2,000,000	Lit. 400,000
*	- Regional expenses	Lit. 180,000
	- Gain with IPM	Lit. 220,000 ≈ US$ 143

* Same figure

Some problems and future evolution

We have already mentioned the fact that the economic help received by the farmers' organizations for every extension officer decreases over time. As the contribution becomes smaller, they give the extension officers other tasks, or require them to cover a greater number of farms. On the other hand, the organizations are not satisfied with a programme that covers only 20% of the farms. They would like an almost 100% coverage. Clearly, this result cannot be achieved without a radical change in the organization of the programme, as simply increasing its size would require unaffordable expenses. In fact, there is a tendency towards the so-called "indirect support": in other words, some farms will always be fully monitored, samples will be taken every week etc.; the information gathered from these farms will be used to give advice to the other ones on a territorial basis, i.e. uniform areas will be identified and a special bulletin published for each. The extension officers will visit each farm only few times a year. This will require better training of the farmers, as the responsibility of decisions will be entirely with them. However, today the better farmers take part into the programme: if the number increases, the technical level is likely to decrease.

However, further costs are covered by the growers' organizations.

Big training effort should be undertaken to give them sufficient knowledge. Other problems will arise from the fact that some pests cannot be easily controlled in a standardized way, even in a small area, without resorting to unneeded, preventive treatments.

A welcome evolution is in progress towards integrated production. This programme initially dealt with plant protection only, but now everyone is aware of the unity of the production process. An experimental integrated production programme is under way and in the future it will substitute the IPM programme. The integrated production of sugar-beet has reached the extension level.

There are also plans for a commercial label that will characterize the products grown under the IPM or integrated production programme. There are, of course, some problems. If a label has to be given, a dramatic increase in the size of the programme is unavoidable: the growers' organizations will not accept that 20% Of their members have a commercial advantage.

Conclusions

The IPM programme of the Emilia-Romagna is undoubtedly the biggest effort undertaken in Italy in the field of integrated plant protection and integrated production. However, though it was set up with the considerable support of the public sector, both the political and economic situation are changing in our country. Therefore a radical reorganization of the programme is under way, and the details of future developments are not clear yet. The risk, as often happens when politics is involved, is that the appearance will prevail over substance. Nevertheless, I am almost certain that responsibility and reliability will continue, as they have until now, to be our guiding principle. Indeed, this is our long-term interest.

The role of extension in the implementation of integrated fruit production in Switzerland

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Summary

"Integrated fruit production" (IFP) including its important component "Integrated pest management" (IPM) has become the accepted goal of apple production in Switzerland. The development and the implementation of the IFP concept was facilitated by close cooperation between extension, growers' associations, and research. These efforts started in the early sixties. The IFP label created by the national IFP organization of the fruit industry in 1990 helped considerably to motivate growers and consumers to adopt the concept. However growers need additional technical support to implement IFP. Therefore strengthening the extension service is essential.

Introduction

Fruit production was a forerunner in the intensification of agriculture. In Switzerland the change from traditional apple-growing with extensively cultivated standard trees to modern plantations of dwarf trees started in the fifties and continued into the sixties and seventies. This development resulted in regular crops of uniform, unblemished fruit which now supply the market throughout the year. Prerequisites for this success were dwarf rootstocks, adapted varieties, appropriate techniques of pruning and the application of fertilizers, fungicides, insecticides and herbicides. Besides the positive aspects of the development, negative aspects soon appeared. The perfect external appearance of fruit was not always matched by internal qualities. Apples were beautiful, but sometimes not tasty and juicy. Physiological disorders such as bitter pit and Jonathan spot increased. Fertilizers, especially nitrogen, which were often used excessively, contributed to the pollution of ground water. Pest and weed management based mainly on pesticides and herbicides was effective but produced backlashes: secondary pests and weeds increased, resistant strains appeared.

The desirability of pesticide residues on fruit was hotly debated: the apple is a symbol of health. The consumer was not easily convinced that some fungicide residues are technically unavoidable and at the same time acceptable for human health. Other negative aspects of pesticides relate to degradation in the soil, with toxicity to soil organisms and with pollution of ground water. Modern fruit production was also criticised for its impact on landscape and biodiversity. Many of the traditional standard fruit trees disappeared causing an aesthetical loss and a loss in botanical and zoological diversity.

Intensification started early in fruit growing. As did efforts to limit negative aspects of this process. Integrated pest management and integrated production combining economic and ecologic goals became an issue earlier in fruit growing than in other branches of agriculture (Wildbolz, 1983). This happened in Switzerland as well as in other European and overseas countries.

Developing and implementing the concept of IFP has been a cooperative effort. The role played by Swiss extension specialists during the past decades has been decisive and shall be discussed in more detail.

How is research and extension organized?

Orchard research is done by the Swiss federal research stations at Wädenswil and Changins, whereas extension services are organized regionally by the cantons. In contrast to some other countries, the research and extension services cover all aspects of fruit production in one institution. So splitting pomology from plant protection is avoided.

The duties of Swiss research stations are threefold: research, registration of agrochemicals, and preparation of supporting material for extension. Therefore, they also act as technical centres of extension. This facilitates the exchange of experiences between researcher and advisor and has proved extremely useful in the development of IFP.

IPM or IFP?

Difficulties in the management of arthropod pests and diseases induced entomologists and phytopathologists to seek IPM as an alternative to conventional methods. Many extension specialists were already enthusiastic about such a concept in the sixties. From the beginning, however, they stressed the necessity of optimizing all aspects of fruit production, not only pest management. The advisor knew better than anybody else that the grower must produce quality fruit using more acceptable methods. As a consequence of such discussions, IFP - with IPM as an important component - has become the undisputed goal of our efforts (Baggiolini, 1978; Stäubli et al., 1986, 1988; Wildbolz, 1988; Wildbolz & Spring, 1990).

Advisor, researcher and growers' cooperation

The story of IFP in Switzerland between 1960 and 1990 cannot be written without mentioning the work done by the pioneers of extension. H. Wunderli (Zürich), E. Keller (Thurgau), K. Müller (Lucerne), L. Favre (Vaud), A. Schmid (Valais) are important figures of the first generation of such advisors. The names of further advisors who became involved later and are still active should be added. All these extension specialists have promoted IFP in slightly different ways and have given colour to today's picture. From the beginning such efforts were well coordinated. On the international level the IOBC/WPRS Working Group "Integrated Control in Orchards" acted as the forum for technical exchange (IOBC/WPRS, 1975, 1976, 1980). In Switzerland different projects and working groups contributed to the coordination and to a good spirit of mutual understanding.

Pilot orchards.

From the beginning IPM and IFP were developed in small scale experiments as well as in commercial orchards. In the different apple growing regions of Switzerland pilot orchards were established. In these orchards researchers and advisors cooperated with growers to test experimental methods in commercial practice. Some methods proved to be unnecessarily complicated and could be simplified without undue loss of reliability. Monitoring arthropod pests and natural enemies has become acceptable to growers by such a process. Judging intrinsic fruit quality before harvest by inspecting the condition of the tree and fruit is another example (Forschungsanstalt Wädenswil, 1985; Spring et al., 1990).

Pilot orchards also became starting points for the generalisation of new methods. Biological control of phytophagous mites by introducing natural enemies was tested. Growers from the neighbourhood visiting the experiments were convinced by the results and copied the method! (Baillod et al., 1989; Wildbolz, 1988).

IFP study groups

During the practical implementation of IFP the need for regular contact between advisors and researchers became obvious. Two groups were created in the east and in the west of the country including extension specialists and researchers of all important branches of fruit production. They meet 2-3 times per year in orchards to discuss recent developments and to initiate new projects.

Plant protection: instruments of extension

Pests and diseases as well as control methods change regularly. Therefore, growers need more technical support than in many other sectors. At the beginning of every year recommendations for plant protection are published. During spring and summer a warning system provides growers with short-term information weekly. For 40 years such information has now been produced by a common effort of the extension services and research stations. This helped to coordinate the advice given to growers by governmental services. In addition, to a large extent it is influencing the advisors of the chemical industry. Contradictions in advice - so difficult for growers to interpret - could so be minimized.

Crucial for IFP: the well instructed, well motivated grower

IFP aims to optimize all aspects of the production process. Instead of working systematically to a fixed plan the grower adapts his measures to the specific conditions of his orchard. The skills necessary for such a task must be provided by schooling and by regular advice. In the last years, the success of the programme was directly related to the quality and intensity of technical support.

The basic instruction of the young grower starts at agricultural school. It continues with refreshment courses organized by advisors and by local growers' associations. IFP has clearly increased the need and the interest for such instructions.

During the growing season the grower has to be constantly aware of the condition of his orchard in order to adapt his measures to requirements. Methods have been developed to judge the growth of trees, the fruit set, the maturation of fruit as well as the pest, disease and weed situation. A record book for use in orchards was created where such records are noted together with data on fertilization, fruit thinning, pest and weed management. Such documents have been formulated in conjunction with supporting pamphlets by the common effort of extension and research. A specialized agency, the Swiss fruit centre Oeschberg, distributes the documents.

The IFP label - a breakthrough

Since 1970, IFP became the undisputed guiding principle in the instruction of fruit growers. Guidelines for IFP were formulated and updated by a committee of advisors, researchers, administrators and representatives of the national organization of the fruit industry (Schweizerische Arbeitsgemeinschaft für Integrierten Obstbau SAIO) (SAIO, 1982/91). However, general agreement on principles was not fully reflected in orchard practice. Regular inspection of trees allows a reduction in fertilizer, pesticide and herbicide use. Nevertheless the additional efforts necessary for monitoring were not recommended in economic terms. Therefore many growers remained sceptical.

This stagnation changed drastically in 1990, when the national fruit organization (Schweizerischer Obstverband), an organization of growers and commerce, launched an IFP label (Wildbolz & Spring, 1990), to identify fruit as being grown to IFP standards. The label became well accepted by growers and consumers. A fruit grower has to undertake to comply with the IFP guidelines and to satisfy their minimum requirements (standards). Each orchard is visited in autumn by a team of experienced growers. This team inspects the record book and the orchards and, where requirements are satisfied, permits use of the label. The system is in the hands of the national and regional growers' organization, but again extension officers play a major part in the instruction of the inspectors. The visit to the orchard under this scheme offers an additional possibility for technical advice. The inspectors will find the weak points of the growing practice and discuss them with the grower seeking ways of avoidance in future. Results of the scheme are impressive: In 1991 nearly 50% of all dessert apples were produced according to IFP guidelines.

Changes and risks

IFP aims to optimize all aspects of fruit production. Apples must have high internal and external quality. The production must follow sound economic and ecologic principles. The approach provides an answer to many of the concerns of the general public toward agriculture. It offers a good chance for sustainable production. A further aspect needs consideration: agriculture is criticized (not without counter-argument) for endangering the diversity and the beauty of the landscape. Fruit growers may help to limit any negative developments. Surroundings of orchards can be managed to harmonise with the landscape e.g. with standard fruit trees, hedges and/or extensive grassland.

Besides all these opportunities, the risks of IFP cannot be denied. The introduction of an IFP label was only possible by establishing clear and controllable rules. Rules are schematic per se. Therefore they are to a certain extent a contradiction to the goal of IFP to adapt the production process to the needs of the specific orchard. They set out minimum requirements. Moreover, rules may be concentrated on points which are secondary in importance but easy to control. There is a risk that IFP may either become rigid and dogmatic or that it may become diluted and loose its essence. Such dangers can be overcome if extension can maintain its role. Introducing integrated methods into agriculture needs more research and more extension to help the grower in his more demanding task.

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The role of extension services in integrated pest management in glasshouse crops in England and Wales

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Summary

The Agricultural Development and Advisory Service (ADAS) has played a major role in the expansion of integrated pest management (IPM) in England and Wales (United Kingdom). Growers have been trained by specialised courses and are kept up to date by the media, group meetings, conferences and visits from ADAS consultants. Research and development (R & D) in IPM is an important part of ADAS work and this is enhanced by collaboration with other researchers of Horticulture Research International and the producers of parasites and predators who also carry out extension work.

ADAS consultants offer a service to the industry and charge for this. Growers of edible crops for which IPM is well established require regular monitoring and updating from their consultants, whereas growers of ornamentals are new to the technique and require more basic support. There is a general trend for growers to seek training for their staff who play an important role in making IPM successful. Consultants visiting nurseries are in the best position to see areas of IPM that need development. ADAS consultants are independent and this helps to exercise some quality control in the management of IPM. They are also suitable people to discover any new pest and in collaboration with the Plant Health and Seeds and Inspectorate, to develop IPM for its control.

Problems for extension workers include a lack of basic biological information and data on what the actual numbers of pest or natural enemies on the crop mean in terms of success or failure of IPM. Increasing complexity of IPM as the number of species of natural enemies that are commercialised increases causes some problems but this is not as difficult as was first feared. A major problem involves the threat of unwise use of new pesticides, particularly those that are potentially useful for IPM.

Advisers have a considerable role to play in publicising the benefits of IPM to the general public in order to emphasise the reduction in the use of pesticides by using biological means of control.

Introduction

Extension work in integrated pest management (IPM) emanates from several sources in England and Wales:-

- The Agricultural Development and Advisory Service (ADAS) which is part of a Government Department and is soon to become a Government agency responsible for its own resources.
- Horticulture Research International which is a body partially funded by Government and which carries out research projects. A small team of researchers at Littlehampton carries out investigational and some extension work in IPM.
- Commercial companies that produce natural enemies and advise customers on their use.
- Commercial companies that act as agents for the supply of natural enemies during their usual business of selling a wide range of horticultural products.
- A few private consultants who include IPM in their general horticultural advice.

The bulk of advice is probably given by ADAS horticultural and specialist advisers who charge growers a fee for time spent on their queries, in much the same way as a private consultant. Advice from commercial companies is ostensibly free though the cost is presumably recouped in the price of their products. ADAS advisers generally visit their customers on a more frequent basis than commercial advisers.

All extension sources collaborate whenever possible. ADAS and HRI formally agree R and D programmes each year whether funded by Government or by commercial sources and several projects are carried out jointly.

Commercial companies carry out their own R & D but also financially support projects carried out by ADAS or HRI. This cooperative atmosphere ensures a thriving extension service in which there is little conflict regarding the best advice in IPM. Throughout the past 20 years extension works in the UK have been able to benefit from the IOBC/WPRS Working Group "IPM in Glasshouses". Participation in conferences and workshops, carrying out coordinated research with European counterparts, exchanging stocks of natural enemies and contributing to and receiving IOBC/WPRS Bulletins and the journal 'Sting' have all contributed to developing a high level of expertise to pass on to growers.

Historical background of the ADAS role in IPM

IPM in protected crops began in the United Kingdom in 1927 when E.R. Speyer provided the first extension service from the Lee Valley Experimental Station at Cheshunt in Hertfordshire. A parasite (*Encarsia formosa*, Gahan) of glasshouse whitefly (*Trialeurodes vaporariorum*, Westwood) was mass-produced and sold to growers until the mid 1940's. However, during the subsequent two decades, the development of powerful pesticides such as the organochlorines and organophosphates reduced interest in biological control. In the 1960's resistance to some of the popular pesticides, especially in pests such as the two-spotted spider mite (*Tetranychus urticae*, Koch) occurred and interest in biological control was rekindled.

In the late 1960's Dr. L. Bravenboer at the Glasshouse Crops Research and Experimental Station at Naaldwijk in The Netherlands evaluated various natural enemies against spider mites and Dr. G. Dosse, a German colleague, provided him with a predatory mite accidentally imported on orchids from Chile. This predator, *Phytoseiulus persimilis* Athias-Henriot, seemed very efficient and was developed further by Dr. Bravenboer and the late Dr. N.W. Hussey who led the research department in entomology at the Glasshouse Crops Research Institute at Littlehampton in England. The predator proved highly effective in cucumbers in the UK. Dr. Hussey developed a close liaison with ADAS advisers and in joint development work they tested *P. persimilis* against spider mites, *E. formosa* against whiteflies and various parasites of aphids in commercial protected crops. Initially, advisers and growers were trained by Dr. Hussey and his colleagues who designed a practical course that set the example for all future training. In the late 1970s ADAS did most of the training of growers in collaboration with the Agricultural Training Board of MAFF. At this time commercial producers of parasites and predators became established.

Throughout the 1970's and up to the present day, researchers and advisers/consultants in protected crops entomology have met annually to assess the requirements for R & D in IPM and to discuss new ideas. Projects were identified and assigned to advisers or researchers as appropriate and unnecessary duplication of effort avoided. The intensity of this activity (Table 1) reflects the emphasis on the biological approach to pest control.

The figures not only show that most effort has been put into IPM but also indicate the various trends in work priorities over the years. In cucumbers IPM worked so well that little effort was needed in the late 70's, this scene changed dramatically following the arrival of western flower thrips (*Frankliniella occidentalis* Perg.) in Europe in 1983. Little work was needed on sweet peppers and ornamentals until these crops expanded in area in the 1980's and western flower thrips also affected these crops.

Table 1. Numbers of experimental reports on IPM compared with pesticides, 1967-87

Period	Cuc	Tom	Pep	Chrys	Orns	Biol	Pest
1967-74	53	46	0	5	6	17	46
1975-80	5	48	0	18	0	4	47
1981-87	27	21	11	28	12	13	65
Total	85	115	11	51	18	34	158

The increasing interest in biological control in the protected crops industry is evident by the increase in area treated with *P. persimilis* and *E. formosa* from 1975 to 1988 (Table 2).

Table 2. Hectares of protected crops treated with parasites and predators in England and Wales

Year	Potential target*	*P. persimilis*	*E. formosa*	Others	Source
1975	695	26	42	0	Gould, 1980
1978	804	272	249	0	Gould, 1980
1983	672	237	247	56	Gould. 1983
1986	604	230	284	13	Wardlow, 1986
1988	587	250	314	16	Wardlow, 1988

* Area of heated tomatoes, cucumbers and sweet peppers.

The area treated with *P. persimilis* also reflects the decline in areas of tomatoes and cucumbers due to high fuel prices in the early 1980's. The use of the predator is now expanding in (a) tomatoes where bees are now used for pollination and pesticides should not normally be used; and (b) in ornamentals and sweet peppers.

The area treated with *E. formosa* expands gradually as its use is extended into ornamentals of which there is an additional potential target of about 200 ha.

The area treated with 'other' natural enemies includes the fungal pathogen *Verticillium lecanii* that was used extensively in edible crops during 1983 but was not a success due to its mis-use; the product is used more successfully nowadays. Since 1988 a wide range of parasites and predators have been developed, including *Amblyseius* spp for the control of thrips, and future surveys will show a considerable expansion in this area.

The specific role of the consultant

One-to-one relationship

Growers are served by both telephone and visits and advice is sought on the following topics:

- biology of the pests
- biology of the parasites and predators
- integration with pesticides
- aspects of resistance to pesticides

- threats from new pests
- the design of IPM programmes

Regular consultation between advisory and research entomologists ensures that a satisfactory service is provided for growers. However, consultants are also able to keep up to date by efficient access to scientific literature and by attending international conferences, in particular those organised by IOBC/WPRS.

General dissemination of information

Advisers need to maintain a high profile in order to be credible and valued by the industry. In ADAS in particular, they need to be independent. They need to publicise relevant information of new developments in IPM and these are transmitted to growers by the following means:

- articles on IPM for both local and national press
- lectures to growers' groups
- organisation of seminars and conferences
- radio and television interviews and talks
- specialised growers' notes and leaflets

ADAS consultants in particular have been adept at using these to increase awareness of IPM, benefiting from good support facilities for producing high quality visual aids. In some European countries technical booklets and posters are frequently used to assist growers in the recognition of pests, their damage and their natural enemies; but these are generally considered too expensive to produce in the UK.

New ideas

Various ADAS entomologists are responsible for organising the R & D for one commodity area of the national IPM programme and commercial consultants and researchers also contribute to the work. Projects include IPM in cucumbers, tomatoes, sweet peppers, chrysanthemums, ornamentals and alien pests. This R & D is based on the need to find solutions to problems confronted in the field. The consultant is therefore aware of commercial problems and is in an ideal position to bring those to the attention of colleagues and researchers. This situation has resulted in good ideas from all extension sources but, for example. Some of these developments instigated by ADAS, are shown below:

- IPM in year-round chrysanthemums
- IPM in sweet peppers
- IPM in poinsettias and other pot plants
- IPM in tunnel strawberries
- manipulation of parasites for leafminers
- development of an egg-parasite of leafhopper
- commercial prospects for a predatory midge against spider mites
- mass production of anthocorid bugs

Quality control

The independent consultant is primarily interested in ensuring that IPM works to the advantage of the grower, the source of natural enemies matters little so long as they perform as well as can be expected. In the heat of competition between suppliers of natural enemies the unbiased ADAS consultant's role can sometimes help to exert some influence on the production companies and keep standards high. It is noticeable in recent years that there is increasing collaboration between ADAS and the companies to ensure the successful expansion of IPM. It is in no-one's interest that this potentially valuable technique should be tarnished with a poor image because of the lack of technology. Extension workers, but particularly ADAS, have laboratory facilities for developing techniques and for monitoring the quality of different components of IPM programmes as follows:

- identification of animals and sex ratio assessment
- assessments of numbers of pests and/or natural enemies
- extractions of animals from plant material
- checks on parasitism of leafminer larvae so that growers can take remedial action before the pests get out of control
- checks on emergence of animals from cocoons/pupae so that growers can confirm quality and avoid failures
- examination of growing media or animals for parasitic nematodes
- viability checks on commercial formulations of fungal pathogens
- provision and assessment of bait plants

Alien pests

By regularly visiting nurseries, the advisory entomologist is the most likely person to discover a new pest. It is important that these pests are discovered and dealt with quickly because the Plant Health and Seeds Inspectorate (PHSI) usually require that they must be eradicated by chemicals that can serious affect IPM programmes. In some cases PHSI will accept that the biological control of the new pest may be possible and the consultant will find a role in monitoring this situation in collaboration with the inspectors.

The changing role of the consultant in IPM

Information

Extension workers can often obtain funding from the horticultural industry to carry out R and D in IPM but these projects are usually of a type that gives reward to justify the cost. Projects funded by Government are done by ADAS and HRI and are therefore more likely to support less attractive, but no less important, projects such as biological studies. However, the recent pace of change in IPM is so rapid that it is difficult to organise sufficient biological investigation to keep up to date. New parasites and predators are being commercialised without the basic biological information needed for their successful use and this places advisers in a difficult position especially when valuable crops are at risk.

Competition

The producers of natural enemies also develop new techniques that help their commercial success and sometimes ADAS may not be involved until the techniques are being commercially employed. This places the producers in an advantageous position especially since any advice will be costed into their products whereas ADAS offers a charged service. Fortunately, increasing collaboration between ADAS and the producers is helping to avoid this potentially serious problem.

Sophistication

Some growers have been using IPM for 20 years and have developed considerable expertise in the technique. Consequently, advisers are having to further raise the quality of advice and to develop new products/ideas in order to be of value to their clients.

Training

Growers are increasingly recognising the value of training their work force in the basics of IPM. Good training not only prevents spoiling of IPM programmes but it also helps to improve their success since staff are usually the first to discover problem areas. ADAS consultants are being increasingly used in this training role and commercial companies are more frequently contributing in this area.

Clientele

The 'green' trend in public life has widened interest in a decrease in pesticide usage and this has favoured IPM by increasing its popularity. Local government authorities find that they can benefit by visibly supporting IPM in their parks and gardens. Retailers of plants and food are finding it useful to have organic sections their supermarkets. Chemical companies can gain credit if they can claim that their products do not harm natural enemies. ADAS in particular is therefore finding that its range of customers is widening and its style is adapting accordingly.

Specific problems for the consultant

Monitoring IPM

In the early days of IPM Dr. Hussey and his colleagues developed the technique of using visible signs of damage to leaves by pests rather than counting the actual animals in order to speed up the assessment of the pest/natural enemy relationship in cucumbers (Anon, 1972), and this leaf damage index technique works well for edible crops. In ornamentals, leaf damage is unacceptable to the retailer so the animals must be counted. Unfortunately there is very little information available regarding the threshold levels at which additional actions may be required to make biological control work.

Complexity

There are now eleven different parasites or predators that are commercially available for biological control (van Lenteren & Woets, 1988). Some programmes may include five or six of these. Many growers receive a weekly delivery of a range of natural enemies that must be divided amongst several glasshouse units. The problem is compounded if the grower obtains his supplies from several sources. ADAS consultants have devoted much of their time to helping growers deal with this complexity and new ideas for simplifying this problem are likely to emerge in future. Commercial companies need to develop their own ideas.

New pesticides

Since fewer pesticides are brought onto the market nowadays, growers are usually very keen to try any new product. As far as IPM is concerned, pesticides either harm natural enemies so much that they cannot be integrated or they may be safe and can be included either wholly or partially into the IPM programme. Most of the available information on this topic is supplied by the IOBC/WPRS Working Group "Pesticides and Beneficial Anthropods" led by Dr. S.A. Hassan at Darmstadt. This group uses standardised tests to evaluate the side-effects of pesticide against each natural enemy and categorises the results from harmless to those causing more than 99 per cent harm. If products in the harmful categories are very successful, growers will often prefer them to biological control and IPM can suffer a serious setback. Any new pesticide that can be integrated may also be preferred and over-used if it is very successful. The 'safer' products are very valuable to IPM and should not be over-used if resistance to them is to be avoided. There may be a just case for controlling their use to prevent this problem occurring.

Costs of IPM

When the use of *P. persimilis* and *E. formosa* became established they cost about the same as pesticide programmes but this was justified because they became the best way to control pests that were resistant to pesticides. Refinements in mass-production techniques and competition between producers reduced prices so that nowadays in tomatoes and cucumbers IPM costs one fifth to one third that of chemical programmes. For ornamentals, IPM costs about twice that of chemicals at present and though this is a problem for promoting IPM in this sector, enlightened growers value the lack of problems involved with using pesticides and the improved quality of crop that ensues.

Diseases

Fortunately, many fungicides integrate well with natural enemies but there are problems of resistance to fungicides and these are likely to increase in future. The lack of prospects for biological control of diseases is of major concern and presents daily problems for the consultant.

The future

In the UK, the horticultural industry no longer needs general publicity on IPM but constant updating is very important. ADAS consultants are ideally placed to satisfy this demand and may also be hired by commercial advisers to update their extension people. In recent years, increasing public interest in environmental matters has encouraged greater use of IPM. Garden centres are proving ideal for demonstrating the value of IPM and gardening programmes on radio and television also generate interest. Large organisations such as the retailers and government departments are supporting 'green' matters but IPM does not seem to get the publicity it deserves in these areas. This may be easier to achieve when an internationally accepted logo for IPM (as is being discussed by IOBC for the fruit industry) becomes established.

Acknowledgements

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Field vegetables in Denmark: An example of the role of the Danish Advisory Service in reducing insecticide use.

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Summary

In Denmark, monitoring-warning systems have been produced for four of the main pests of field vegetables: turnip moth (*Agrotis segetum*), carrot fly (*Psila rosae*), cabbage root fly (*Delia radicum*) and pea moth (*Cydia nigricana*). The Advisory Service has been intimately involved in the implementation of the first three systems.

After a period of development of approximately 5 years, during which time the systems were subsidized by growers' organisations, the use of monitoring-warning systems are now considered to be a routine part of crop protection practices. Hence they are now managed by the Advisory Service, who offer them as a regular service that interested growers can buy. The use of the monitoring-warning system for the carrot fly and turnip moth have reduced the amounts of insecticide use applied by participating growers by 65-80% of the amounts applied previously.

Close contact and cooperation between research institutes, participating growers and the Advisory Service have been essential to the success of the development and implementation of the monitoring-warning systems.

Introduction

Danish field vegetable production

Commercial field vegetable production in Denmark dates back to 1518 when King Christian II sent for a group of skilled Dutchmen to cater for Copenhagen's requirements of fruit and vegetables. Subsequently vegetable production developed around the major Danish towns. Today 14,470 ha used for field vegetable production are scattered throughout the country, and supply 85% of Denmark's requirement for vegetables. Most of the production takes place on specialized vegetable farms on which the dominant crops are peas, carrots, onions, cauliflower and salad crops (Table 1).

Danish Agricultural/Horticultural Advisory Service

In Denmark, the Advisory Service is controlled by agricultural and horticultural organizations and supported by the Government. In this way, the growers ensure that the Advisory Service directs its effort towards the requirements of the users. Neither commercial considerations nor political interests control the Advisory Service. In field vegetable production, the Advisory Service is controlled jointly by The Danish Farmers' Unions, The Danish Family Farmers' Associations and The Danish Association of Horticulture Producers. There are three regional offices, each with 2-3 advisers who are supported with technical back-up from the Agricultural Advisory Centre. The activities of the advisers are financed by membership subscription, by user payment and by Government grants (approximately 20%).

Table 1. Area of major field vegetable crops grown in Denmark in 1987

Crop	Area (ha)
Cabbage	850
Cauliflower	731
Brussels sprouts	144
Leek	444
Celeriac	187
Beetroot	204
Carrots	1,353
Onion	970
Lettuce	190
Chinese cabbage	454
Pea	7,456
Total	14,470

(Source: Danish Agricultural Statistics 1987.)

Pesticide use and environment

In Denmark, public concern about the environment has increased the pressure to reduce the amount of pesticides applied to crops. The Government's aim is to reduce the use of pesticides before 1997 to 50% of the quantity used in the years 1981-1985.

As vegetables are high-value crops, Danish vegetable growers have a special interest in and motivation for bringing their production not only in line with the legislation but also with the public demand for safe food without negative effects to the environment. To achieve this, a range of alternative measures are being studied. To date, monitoring-warning systems have proved to be the single most important measure for minimizing the use of pesticides. The systems indicate when spraying is not required, provide early warning of when to spray and assist in timing of spray applications accurately.

Monitoring-warning systems

Monitoring-warning systems have been developed for: turnip moth *(Agrotis segetum)*, carrot fly *(Psila rosae)*, cabbage root fly *(Delia radicum)* and pea moth *(Cydia nigricana)*. The Advisory Service now is involved in the implementation of the systems for turnip moth, carrot fly and cabbage root fly. The system for pea moth is used mainly by a processing company that contracts growers to produce peas for deep-freezing.

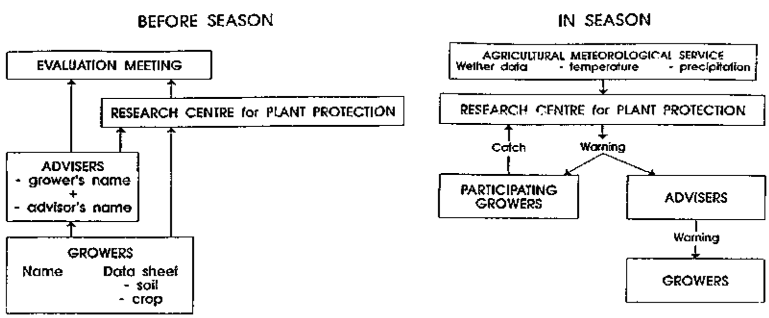
There are fundamental differences between the systems. For example, carrot fly and cabbage root fly are serious pests every year, whereas turnip moth populations reach critical levels only in certain years. However, for all three insects there is considerable variation from site to site in the timing of pest activity and in the size of pest population. This means that, to monitor when treatment is needed, traps have to be placed at strategic locations in the region or on the farm. In the case of the carrot fly, one set of traps per farm may not be enough. Ideally, traps should be placed in each carrot field. However, this is not economic as monitoring costs are high. In practice, therefore, one set of traps is recommended for each 5 ha of crop.

Another important aspect is timely treatment as once larvae begin feeding on the roots, they cannot be reached by sprays.

Turnip moth (cutworms)
A monitoring-warning system for turnip moth has been operated by The Research Centre for Plant Protection since 1980. The system is based on metal tray-traps which dispense a synthetic pheromone to attract turnip moths. An evaluation of the risk of cutworm damage involves five parameters: catch of turnip moth, crop, soil type, amount and number of days with precipitation and temperature and are all set in relation to treatment thresholds (Esbjerg, 1989). The warning system operates on a nation-wide network that involves a few research stations and approximately 30 growers selected by the Advisory Service. As many growers can use the results as a guideline for treatment without having their own traps, the growers' organizations now pay for the traps used by the selected growers.

The results obtained from the participating growers are used by The Research Centre to send recommendations back directly to the participating growers. The results are also used for more general warnings that the Advisory Service distributes in their regular newsletters or in special warning letters. Figure 1 shows a flow chart of the events involved in the monitoring-warning system for turnip moth. The system provides a sound basis for general warnings of cutworm attacks. Advice on treatment ranges from irrigation of the crop to timely spraying. Growers who have followed advice based on this system have reduced the use of insecticides by approximately 80% and damage levels have been maintained under 1% (Esbjerg, 1987). One difficulty in keeping growers within the network, is that there might be 5-6 years between a "positive" warning.

Figure 1. Organization of monitoring-warning system for turnip moth (*Agrotis segetum*) (partly after Percy-Smith 1990)



Cabbage root fly
A monitoring-warning system for cabbage root fly started by The Research Centre for Plant Protection has now been operating for 6 years. Traps placed around brassica plants are used to collect fly eggs, the eggs being counted every 3-4 days. The warnings are based on the number of eggs collected. At present, approximately 40 growers are using the traps and approximately half of these report their egg numbers to The Research Centre. An unknown number of growers rely on the general warning. The system has proved suitable for warning of attacks by the cabbage root fly and has shown differences of 5-7 days between regions in the start of egg-laying. However, cases of extensive damage indicate that growers should not rely only on a general warning but should use traps in their own fields. One of the reasons for this recommendation is that the time interval between egg-laying and applying a timely treatment is

extremely short. Generally, the monitoring-warning system has led to fewer insecticide treatments. However, cabbage root fly still has to be controlled in most crops.

The Advisory Service has until now been promoting the use of traps and assisting the growers in determining timely spraying.

Carrot fly

The yellow sticky traps used for monitoring carrot fly were developed originally for research purposes.

In 1984, The Research Centre for Plant Protection started the monitoring and warning system with 14 participating growers. Based on the experience from the turnip moth monitoring-warning system, the growers' organisations supported this system from the beginning by subsidizing the participating growers. It seems as if the earlier system served as an important incentive to keep the growers interested in using traps. After a steady increase, there was a large rise in the number of participants in 1987 following the involvement of two processing companies. At present, using yellow sticky traps to catch the carrot fly is the most widespread monitoring-system in Denmark. There are now approximately 130-140 participants and on average a density of about one set of traps for each 10 ha of carrots.

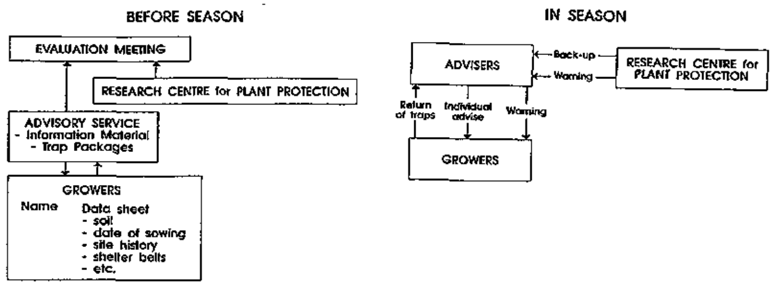
One constraint on the use of yellow sticky traps, is the need for a trained person to service the traps. This was initially done by The Research Centre for Plant Protection and was paid for by the participating growers. However, this work is now considered to be routine and the local Advisory Service has, in most areas, taken over the monitoring-warning system. The Research Centre now serves solely as back-up (Figure 2). The original subsidy has been gradually reduced to accustom the growers to pay full the costs, and 1991 the subsidy stopped. Growers now have to pay 1000 DKK for a set of traps, including servicing, for one generation of the carrot fly. Considering the work involved, this price is too low.

The present carrot fly monitoring-warning system is organized in three different ways. Firstly, in N. W. Zealand at Lammefjorden close to The Research Centre there is a large concentration of growers producing carrots for the fresh market. Here the traps are still serviced by a person from The Research Centre, who visits the growers weekly. Secondly, the system administered by the local Advisory Service is based on geographically scattered carrot growers. These growers send their traps to the Advisory Service each week so that their flies can be identified and counted. Finally, on the island of Funen, where most of the carrots grown for processing are concentrated, the monitoring is carried out collaboratively by the Advisory Service and the processing company. The number of growers involved allows the Advisory Service to employ a person to service the traps weekly. In the first two cases, the growers' participation is voluntary. However, growers producing carrots for the processing company have to participate in the monitoring-warning system as this is part of the contract. Figure 2 shows the sequence of events involved in the monitoring-warning system for carrot fly. The system is based on individual participation and has not proved suitable for a general warning system.

Guidelines have been worked out based on weekly catches in 5 traps. Catch levels are expressed as number of flies per trap per day (Esbjerg et al., 1988). Based on practical experience these guidelines are revised yearly.

Experience shows considerable variation from site to site, sometimes even from field to field. This means that individual advising is an essential part of the system. Spray decisions are made after taking into account the site history, the date of drilling, extent and the orientation of shelter belts etc.

Figure 2. Organization of the monitoring-warning system for carrot fly (*Psila rosae*)



The conclusions are that the system provides a good basis for determining

- when carrot fly problems start
- when carrot fly problems end
- when, and where, there are high carrot fly infestations
- when there are no carrot flies

The weakness of the system is when only a few flies are caught, as this provides no clear indication of whether a treatment is needed or not. Nevertheless, the insecticide treatments in both fresh-market and processing carrots have generally been reduced by approximately 65% of the amounts applied previously (Esbjerg et al., 1988). Where possible, the growers are using a combination of chemicals and other control methods. They include the early harvesting of crops considered to be at risk and taking fields out of production if they have been in high-risk areas for some years.

Cooperation and communication

Close contact and cooperation between The Royal Veterinary and Agricultural University, The Research Centre for Plant Protection, participating growers and the Advisory Service have been given high priority in both the development and the implementation of these monitoring-warning systems. In particular, the communication from The Research Centre to the growers has been given very high priority so as not to lose the growers' confidence and interest. At a certain time, this led to a situation where the advisers felt that the growers were better informed than the advisers. Although the communication between The Research Centre and the Advisory Service has been good, the biggest problem concerning the implementation has been to define the roles of The Research Centre and the Advisory Service. This has been a problem, particularly in the case of the carrot fly monitoring system, as this served for a period as an income for The Research Centre. However, most problems that occur during a season are solved at a yearly evaluation meeting between The Research Centre and the Advisory Service (Figures 1 and 2). Such meetings are also attended by people from the University and from the processing companies. These meetings have shown that Advisory Service involvement is very important, as the advisers know best those areas that need improvement. Another problem is a shortage of resources during the implementation phase, which limits the number of interested growers, particularly if they are expected to pay for an unproven system. Without the financial support of the growers' organisations during the implementation phases, the monitoring-warning systems would not have reached their current level of success.

The most important communication channels are bulletins from The Research Centre to the participating growers; leaflets describing the biology of the pests and the monitoring-warning systems; and from the Advisory Service newsletters and special warning letters. Furthermore, field-days, meetings and courses are important sources of information.

Discussion

Consumers' increased awareness of pesticide use in vegetable crop production has made the growers interested in adopting techniques to reduce insecticide use. However, introducing research results into commercial vegetable production is a lengthy process which requires high input of knowledge and management. In this process the Advisory Service plays an important role. However, with the increasing demand for advisers to earn money, it is important that resources are allocated not only to develop new techniques but also to implement them. Another important aspect is that the researchers should respect the competence of their advisers and not try to compete with them for the money available for implementation. Advisers should be allowed to develop their own advice packages. Such packages not only make up an important tool for the Advisory Service but also contribute to an increased income at a time when Government policy is to reduce spending on public services.

Although monitoring-warning systems still have shortcomings, and chemical treatment is cheap, the introduction of these systems has been a big step forward and has decreased insecticide use and increased growers' income.

However, to date very little has been done to communicate to the public the achievements obtained by using the monitoring-warning systems.

In the present discussion about integrated farming systems, monitoring-warning systems play an important role and have a high priority in future developments within vegetable production in Denmark.

The current work includes improvement of techniques, development of monitoring-warning systems for pests like aphids, and development of monitoring-warning systems for plant pathogens. When combined with other alternative measures, such as growing resistant varieties, they should help to reduce pesticide usage even further.

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Closing Address

Options for integrated agriculture in Europe

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Summary
The development of sustainable agriculture is more and more accepted as a long term objective for agricultural research in general and for crop protectionists more specifically. The possibilities for integrated agriculture in the European Community are described in this paper. It can be characterized in many cases as crop production at high yield levels with per unit of product a very high efficiency of use of inputs such as nutrients and crop protection measures.

Scenarios are described in which the possibilities of various ultimate aims of land use at the level of the European Community are made explicit. When agriculture is concentrated at agriculturally well endowed land Resource use efficiency is highest and consequently negative side effects for the environment lowest. This requires a strong research supported integrated agriculture in these areas. The IOBC/WPRS has the lead in the development of such agricultural systems and should maintain that.

Introduction
During the last 10 years integrated agriculture has been intensively discussed within various circles. The International Organization of Biological Control, West Palaearctic Regional Section (IOBC/WPRS) has contributed considerably to that discussion. In that period the IOBC/WPRS developed from an organization of scientists who study possibilities of biological control of insect pests and mites in various agricultural systems into an organization that promotes the development of crop and cropping systems in which preventive and curative biological control methods for pests and diseases are optimized. This means a shift from an organization dominated by entomologists into an organization where entomologists, phytopathologists and also agronomists gather.

It became increasingly clear that single-issue activities are not sufficient and are in some cases counterproductive for the development of an environmentally friendly and viable agriculture. Sustainability became a buzzword. The development of sustainable agriculture has become a major aim of the IOBC/WPRS. In the coming decades such an agriculture should be developed and implemented. But what is sustainable agriculture and what is the role of research in general, and more specifically of the IOBC/WPRS, in this goal?

Concepts
The concept of sustainable agriculture has received much attention during the last decade. It was introduced in the well known Brundtland report. The concept means that the present generation considers in its activities the needs of future generations. This implies that the present generation has to know the needs of future generations. These are not defined and require an explicit definition. For that reason the concept of sustainable development is loose in its definition. It indicates a direction but is not an explicit description.

In agriculture sustainable development can be worked out. However, economists, ecologists and agronomists very often have different interpretations and each discipline has its own interpretation. Some consider that "sustainable" is not a particular form of farming of a certain piece of land, but emphasize that what has to be sustained are rather the possibilities to maintain farm employment at such a level that a decent modern livelihood for farmers and their employees is guaranteed. Then labour replacing techniques and inputs, such as tractors, threshers and herbicides, (which replace labour by cash purchases, and require more skilful management to sustain the environment) are not desirable and hence there is a strong reluctance against any subsidy and research into such inputs. This definition is therefore ambiguous. In agriculture a more elaborate description is desirable.

Agriculture should be both productive and sustainable. This may imply that, from the ecological viewpoint, renewable resources are maintained, non-renewable resources are used with foresight and the intrinsic value of the environment is recognized. From the socio-economic viewpoint, farm families should be able to make a decent living and the increasing and changing demands for agricultural products should be satisfied at reasonable prices. The goals and boundary conditions are thus qualitatively formulated and this may help to reach consensus between groups of people representing different interests. However, it does not reveal clearly the way farm policy and agricultural policy should be implemented. The objectives are conflicting.

A political, rather than a scientific, debate is needed to reach conclusions about how conflicting objectives of productivity and sustainability are matched. The outcome of such a debate depends on political and ideological views rather than on biotechnical or technical-economical possibilities and limitations. It is, however, the task of science to rationalize the debate and to distinguish facts from opinions and beliefs. Too often the 'sustainability' issue has led to mystification and conservation of strategies and methods that are counter-productive, in the sense that they divert from agronomic, socio-economic and environmental goals.

For this reason explicit discussions on sustainability should take place and various concepts should be described and made operational. An important issue in every concept of sustainable agriculture is the management of renewable and non-renewable resources. Integrated agriculture may be considered as one concept of sustainable agriculture. It aims at resource management that best serves various goals. Agricultural goals, such as maximization of productivity and minimization of cost, and environmental goals, such as minimization of the use of pesticides per unit of product and/or per unit of acreage and minimization of emission of nutrients per unit of product or per unit of acreage, should be achieved.

Resource management

For ages the need for more food for an increasing world population has been met by using more agricultural land. When population numbers were low sustainable farming systems were developed, in the sense that they were continued for ages. Examples of such farming systems are shifting cultivation in tropical forests, and rainfed, bunded rice production in Asia.

However, in most situations productivity demands overruled sustainability demands, so that soil resources were over-exploited. Vast areas of once good agricultural land have been lost and become deserts, due to mismanagement and subsequent wind and water erosion, exhaustion or salinization, and ultimately resulted in land that can no longer be used for agriculture. Well known examples are the bare hills in the Mediterranean region, the saline soils in the Middle East, the mining for nutrients of common agricultural land in Western Europe ('tragedy of the commons') and the destructive dust storms in the 1930's in the USA.

It is only in this century that various methods were developed by which productivity demands could be fulfilled and overuse of agricultural land might be prevented. The slow increase of productivity during centuries accelerated in this century as a result of better agricultural methods: green revolutions took place. The first green revolution in the industrialized Western world took place during and shortly after World War II. This revolution, a discontinuity in the increase in productivity, from a rate of between 2-5 kg grain equivalents per ha per year to 80-200 kg grain equivalents per ha per year, was due to innovations coming from various disciplines: better and more timely water management, mechanization, higher soil fertility by the use of more and synthetic nitrogen fertilizers, a better control of weeds, pests and diseases through the use of biocides and improved crop varieties with higher harvest index and more resistance to pests and diseases. This high increase in productivity per unit of acreage was combined with an even higher increase in labour productivity, due to mechanization, other agronomical methods such as chemical weed control and better farm structures and organization.

For example, the production of a single ha of wheat in the Netherlands required about 370 hours per ha at the beginning of this century, whereas now 10-15 hours per ha are needed. In the USA and Australia this is even less, not more than 8 hours per ha. Yield levels in the Netherlands rose from c. 1100 kg per ha in 1900 to 7500 kg per ha^{-1} at present (Fig. 1), so that labour productivity increased c. 200-fold. Similar increases in productivity are found in other crops such as potatoes, rice, maize and onions.

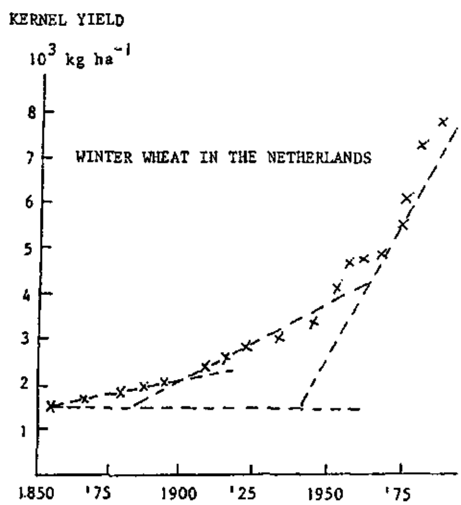

Figure 1. Average yield of winter wheat in kernels (kg dry matter per ha) for The Netherlands from 1850 to 1985

A very important role in the increase in productivity was played by crop protection. The possibility of eliminating crop growth-reducing factors, such as pests, diseases and weeds, was extended considerably by the introduction of pesticides earlier this century. The increase in pesticide use after World War II may have enhanced crop productivity, on the one hand, but pesticide overuse and limited pesticide selectivity may have polluted and destructed natural resources on the other hand. The promotion of biological control, integrated pest and disease management and integrated agriculture may eliminate the negative effects of pesticide use and in that way promote a proper use of resources in agriculture.

The green revolution in the Western industrialized world coincided with a decrease in the number of people to feed, and although diets became more luxurious with more meat, increase in production was so high that a net import of food in Europe until the 1980's changed into a surplus of food in the European Community nowadays. This now creates difficulties for the Common Agricultural Policy and may affect agricultural development in developing countries, as the food surpluses of the EC are dumped on the world food markets where developing countries try to sell their agricultural commodities. In the EC policy decisions are needed which take into account the development in many third world countries.

The first green revolution in the industrialized world was followed by a second green revolution in many developing countries. Productivity per unit of acreage increased considerably from about 2-5 kg grain equivalents per ha per year before 1968 to 125 kg grain equivalents per ha per year in the 1970's and 1980's (de Wit, 1987). Despite an almost three-fold increase in the third-world population since 1945, global food shortages have been averted and the occurrence of famines has been reduced in both number and size. The green revolutions have improved the world food situation even though the world population has increased from 1 billion at the beginning of this century to over 5 billion nowadays. The increase in population continues, especially in the developing world. To feed all these people a considerable increase in food production is still necessary, not only because of an increase in the number of people but also due to the change in diet at increased incomes.

Possibilities for increasing food production are still there. There are still large land areas that could be reclaimed in some parts of Africa and South America, but in many regions of South-East Asia most of the land that is suitable for some form of agriculture is already in use. In South-East Asia more than 50% of the world population is fed from an area of not more than 8% of the cultivatable land of the world. In these areas production levels are already very high and the use of pesticides causes the well known problems in this region. An urgent need for an integrated agriculture is obvious. In other places the possibilities for increasing productivity per unit of acreage are still very large, since most agricultural production takes place in situations where water and/or nutrients are limiting during at least a part of the growing season. About 90% of agricultural production in the world takes place far below potential levels. In developing countries most agricultural production takes place at levels below 30% of what is potentially possible. The potentials for increasing production are still so large in most countries of South and Central America and Africa, that the increase in population size could be met.

An increase in production per unit of acreage and per man requires an increased use of external inputs from the industrialized sector of the economy. For that reason, large scale reconstruction and reallocation of land in those regions with agricultural perspectives is needed. When production is concentrated in well endowed regions and overuse of inputs is prevented, optimal production systems may be developed in which efficacy and efficiency of inputs is optimized and negative environmental effects are minimized.

In the often too intensive agricultural production systems in North-Western Europe this would usually mean a reduction of inputs, whereas in situations elsewhere an increase of inputs would be needed. This is due to the big discrepancy between "Best Technical Means" and "Present Practice".

Best Technical Means are defined as the production technique where each of the external inputs is used at a minimum level in such a way that the efficiency of each of the variable inputs is maximal. This holds for all variable inputs, such as nutrients and pest, disease and weed control. In general Best Technical Means have the highest efficiency at high levels of production per unit of acreage. Given the yield level, dictated by environmental conditions such as water availability Best Technical Means lead to the highest efficiency of inputs per unit of output. As many of the variable inputs, such as pesticides and nutrients, are low in price per kg and high yield levels are aimed at, the tendency to overuse is obvious. This is mainly due to the extremely low price of such inputs in relation to the price of the end product. By imposing an eco-tax on pesticides and nutrients overuse could be impeded and other techniques leading to Best Technical Means would be promoted. Present Practice with overuse of pesticides will then decrease.

Recent analysis of resource management (de Wit, 1990) confirms the notion that the so called law of diminishing returns is absent in agriculture when the inputs for various purposes are mixed in the proper way. De Wit demonstrates that, in many cases, the efficiency of resource use increases with increasing yield. This is due to a synergy of various inputs. When this does not hold unlimitedly, it is definitely true at lower production levels.

These considerations would lead to the conclusion that for environmental reasons, such as minimizing emission of nutrients and maximizing outputs per unit of input, a concentration of agricultural production should be advocated in well endowed regions. For technical reasons this may be preferable. In combination with a proper crop rotation in arable farming avoiding too narrow rotations, and as a consequence high yields per crop and properly applied inputs, this will lead to optimal use of inputs.

Crop protection is a small though vital part of agronomical measures. The development of measures tailored to the needs of individual fields requires a wide range of crop protection research. Much of that research has already resulted in practical advice and recommendations. The implementation of integrated agriculture not only is a matter of research and extension; it also is highly important to create the conditions for incentives to use biological control instead of preventive chemical control methods. An example of such conditions could be the mentioned eco-tax on cheap and environmentally unfriendly compounds, and eventually a (temporary) subsidy on more environmentally friendly techniques and compounds.

Converging and diverging developments

In detailed studies on agricultural development in the EC it was shown that the distribution of production in the various regions is skewed. The agriculturally well endowed regions are producing an ever increasing part of the total production volume. When a maximum is set to the total production (e.g. aiming self-reliance) to facilitate entrance to the world market for developing countries, [due to a continued increase of productivity per unit, for the reasons mentioned above (distance between actual and potential production and greater production efficiency at higher production levels), the total amount of cultivated land in the EC should decrease with at least 40 percent in the coming decades]. Some figures may illustrate this: At present the EC has 128.10^6 ha of cultivated land and 10.10^6 farmworkers. In scenarios that presume production methods according to Best Technical Means on the best land, the same production volume may be achieved at between 30.10^6 and 70.10^6 ha of cultivated land and with 2.10^6 and 5.10^6 farmworkers, respectively. In those scenarios pesticide use may be reduced by 70 to 80 percent. Marginalization of agriculturally less endowed regions is not a new phenomenon. Contraction of agricultural areas also took place in the 10th and 17th century in many areas of Europe, due to decimation of population numbers caused by epidemics. Recently abandonment of vast tracts of land in, for instance, the USA also illustrates such developments. The fact that there are regions where agricultural production continues to increase and regions where agriculture disappears as an important source of income has divergent consequences for agriculture, both in economic and in ecological terms. Nowadays, continuity in economic terms is impossible for all those who find a living in agriculture in the less endowed regions. Off-farm employment and stimulation of other economic sectors seem the only way to go. Still, for ecological continuity, farming or other forms land use seem necessary to prevent degeneration. Ranching, forestry, nature development and conservation are probably feasible, although very extensive options, both in terms of labour and other inputs. In this way a bimodal agricultural production situation may occur, on the one hand intensive, highly productive and environmentally sound agriculture, on the other hand very extensive, poorly productive and also environmentally sound agriculture, which is more a form of land and nature conservation.

This phenomenon of bimodality in agriculture will take place on all scales, be it at country, regional, or supranational level. The continuity of agriculture and maintenance of environmental integrity seem best guaranteed in this way. To guide such developments and to see in what way developments which occur too quickly can be mitigated by government policy or support, scenario studies at various scale levels are needed. The first and second green revolution, like any revolution, know their victims; as developments in the near future will be as radical as during the last decennia, policy makers should be aware of this and act accordingly. This may mean that support of agricultural development in agriculturally less endowed regions at the cost of production in well endowed regions may be necessary for political reasons. This will happen at the expense of efficient resource use, but other objectives such as socio-economic convergency or political stability may very well be worth it.

Sustainability and aggregation levels

Sustainable development in agriculture requires insight as how to produce and manage resources at various aggregation levels. Most discussions on sustainability take place at the crop level. Detailed analysis of nutrient uptake, nutrient use and functioning of crops, the role of weeds, pests and diseases, water management etc. are done for different crops. This crop level dictates the types of disciplines involved in the design and development of crop systems that minimize inputs per unit of output, minimizes pesticide input per unit of product and maximize output per unit of labour. A great deal of plant physiological knowledge, agronomical knowledge, soil fertility studies, irrigation studies, breeding, crop protection studies and, to integrate them all, production ecological studies are needed. Such insight and knowledge may lead to optimal use of inputs and maximization of outputs per unit of input. However, it should not be a single-issue activity but a whole integrated crop management system. Single issue management systems are not profitable and acceptable for farmers.

A second level of aggregation is the cropping system level. At this level rotations and/or mixing of crops are considered. To minimize external inputs per unit of output excessively dense cropping systems should not be used. Again, various disciplines, such as agronomy, crop protection and soil science, should contribute to the development of various cropping systems.

However, in many cases the biotechnical possibilities and limitations do not determine production; limitations and possibilities at farm level are more important determinants. Therefore studies at the farm level are very important. How agronomical measures are determined, for example socio-cultural considerations, labour allocation, tradition and other factors, may govern decision making rather than biotechnical efficiency or purely economic goals. To integrate biotechnical, and socio-economical studies at this level, various procedures and methods have been developed.

A synthesis of disciplines and a synthesis of concepts are needed for that reason. Farming systems research may contribute there. Proper analysis and description of farming systems is necessary to enable the development of strategies and methods. Agronomists working at the crop level have the tendency to overestimate the possibility of changing agronomical measures, as they are not familiar with the background of agronomical systems in which tradition, property rights, religion and other non-biotechnically determined factors play such an important role. Very often the idea occurs that, due to lack of knowledge, farm systems operate below optimal levels. That very often is not true. For example pastoralists in the Sáhelian region exploit the excellent pastures in the north of the Sahel at the border with the Sahara during the short rainy season by transhumance and survive the rest of the year in the south of the Sahel, where little fodder but sufficient drinking water is available during the dry season. This herding system is labour intensive, but measured by production per unit acreage, it is the most productive system that can be visualized under such agro-ecological circumstances (Breman, 1982). Any attempt to improve production by introducing other techniques will fail when the introduction of external production resources is not considered.

This example demonstrates that any intervention or proposal for change should be based on a detailed analysis of both the biotechnical and socio-economic characteristics, the possibilities and limitations of present systems, as well as a good evaluation of the potential for change.

Farming systems operate at regional levels. At this level other analyses are needed. Again, a clear formulation of various concepts of sustainability is required. The distinction between agrotechnical, socio-economic, environmental and spatial objectives should be formulated explicitly in such a way that they can be made operational. From the very beginning it should be made clear which part of the rural economy is taken into account. Such studies may help to rationalize decision making at the regional level and to design various strategies rural for development. Examples of such programs are scarce. However, in some places in South-East Asia, Western Africa and Central America efforts are made to develop such methodologies. The need for such studies is amplified by the emphasis on environmental issues, the tendency to move progressively into marginal agricultural land with more and more environmentally hazardous developments.

The last level at which additional studies are urgently needed concerns the national/supra-national level. At this level international political interests and objectives dominate. Such developments determine the possibilities within lower levels. They determine "the weather" under which the regions function. Strategic studies should demonstrate the opportunities for choices local governments possess and make clear how various issues, such as environmental objectives, determine the limits for decision making. In the Netherlands such studies at the

European level have been done by the Netherlands Scientific Council for Government Policy (WRR, 1992).

Perspectives for integrated agriculture in Europe

The study at the European level done by the Scientific Council for Government Policy demonstrates the possibilities for various developments in rural areas. In all options and scenarios reduction of cultivated land is found. The bimodality described above is present in all scenarios. Total amount of required food can be attained on a very small part of the total land area. The size of this area, be it 30.10^6 or 70.10^6 ha, depends on the preference for various goals. For example, to reach environmental objectives production techniques that minimize use of pesticides below the optimal use of pesticides per unit of product may then be applied more generally. Therefore, more acreage is then needed. This is not much more than the situation in which Best Technical Means, as described above, are applied. The maximum of 70.16^6 ha is much less than the 128.10^6 ha of cultivated land in the European Community (12 countries) and can be higher (90.10^6 ha) when more extensive land use is promoted. The reduction of pesticide use in all scenarios is tremendous. At present over 400.10^6 kg active ingredients are used in the EC, whereas in the scenarios a margin of 40.10^6 to 90.10^6 kg active ingredients is found. The considerable decrease in pesticide use is due to three different reasons.

1. The area on which pesticides are used is much smaller than the present area. The higher productivity per ha causes a less than proportional increase in pesticide per ha.
2. The use of pesticides due to narrow crop rotations, for example 1:2 potatoes, is eliminated. Through structural adjustment of farm size and farm structure excessive use of pesticides, such as soil fumigants against cyst nematodes, is no longer necessary.
3. The application of integrated pest and disease management systems is standard in all crops. This operates where farmers' risk is very limited.

These figures illustrate that the potential for pesticide reduction, without decreasing the economic and agricultural viability, is possible. However, it is not a process that will take place autonomously. It is a possibility that is only realized by promoting an increase in productivity within well defined environmental limits. A ban on too intensive cropping systems is not possible, but the conditions that urged such an intensification beyond Best Technical Means can be eliminated for economic reasons.

The development, implementation and continuous updating and upgrading of IPM-systems is a considerable task for research but an appealing and rewarding one. The IOBC/WPRS could take the lead in that development. Thus, the IOBC /WPRS may help in the development of crop production systems that are more sustainable than many current agricultural practices.

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Conclusions

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Recommendations

Conclusions

1. The Conference succeeded in uniting the interests of scientists, policy makers and extension specialists in aiming at a significant reduction in the use of pesticides in Europe by intensified implementation of biological control and integrated crop protection. Such common interests and efforts are essential to stimulate and co-ordinate activities in integrated pest, disease and weed management in the near future.

2. Four decades of research in Europe in biological and integrated control, co-ordinated by the IOBC/WPRS, have resulted in some crop protection and production systems with a significantly lower need for pesticide inputs (30-85%, exceptionally 95% reductions). The economic and ecological feasibility of several systems has been proved and they can therefore be implemented on a much larger scale than at present. (See Appendix 1 for examples).

3. A number of European countries has recently developed a new national policy for crop protection aiming at a considerable reduction of pesticide inputs and based on principles of integrated protection and production. EC policies in crop protection are still lacking, but urgently needed in order to be able to harmonize national policies.

4. A survey of the conference participants revealed ten major constraints to implementing integrated crop protection. (See Appendix 2). Extension is the key instrument to implementing integrated protection and production systems as they are initially knowledge intensive. Nevertheless, many governments are currently substantially reducing their budgets for extension through processes of privatization.

Recommendations

1. The EC should, as soon as possible, agree on a new crop protection policy based on principles of integrated protection and production. Such a policy should then form the basis of EC regulations on phytosanitary matters, pesticide registration and legislation. For specific remarks, see recommendations 5 and 6.

2. The EC should develop a Research and Extension Programme specifically on integrated protection and production in order to accelerate the development and implementation of these environmentally safer methods.

3. National governments should develop new national crop protection policies attuned to the specific circumstances and needs of their countries.

   If integrated crop protection is to have a future, then government policies to support the introduction of environmentally safer crop protection methods are essential. Such policies should include well defined targets in order to be able to determine progress. It is important that these policies should be developed before 1993 by those countries where such policies are currently lacking, so that deterioration of the crop protection situation in neighbouring countries and unequal competition are prevented.

   Current pesticide registration and legislation directives relate insufficiently to integrated crop protection.

   Registration procedures for biological control agents are unclear and too time-consuming; they should be tailored to the type of biocontrol agent to be registered. Legislative measures should be established which result in easier/cheaper registration procedures for selective and biopesticides.

   Pesticide levies (see recommendation 6) should not only be regarded as a financial instrument, but also as a means to improve the environment.

4. Realization of an environmentally safer crop protection policy necessitates additional research and, therefore, increased funding.

   Research to find biological methods to control specific pests and diseases should be encouraged and increased. Current research programmes concentrate on the control of insects and mites but increased investment needs to be made in biological control of diseases and weeds especially, and also nematodes.

   Although there are several integrated control programmes which are successful, others are incomplete in that they deal only with a limited number of pests, diseases and other constraints which need to be managed in a crop. This makes commercial use of such program-

mes unreliable and therefore unattractive. Extra research input is thus needed (1) to integrate available methods into entire crop production schemes, and (2) to integrate the control of pests and diseases with other inputs, such as fertilizers, reductions of which are equally as important. The development of completely integrated crop production packages requires substantial research investment into Integrated Farming Systems which ultimately provide the most environmentally safe framework for implementing integrated crop protection methods. These would allow more vigorous exploitation of complementary control methods, such as crop rotation and durable host plant resistance, which is greatly to be encouraged.

5. Since integrated protection and production demand high inputs of knowledge, particularly in the introduction phase, national governments should increase their budgets for extension activities and services so that the effectiveness of this crucial instrument in integrated protection and production can be improved.

   The present trend in Europe to reduce state/federal extension services is interfering negatively with the need for increased efforts to introduce integrated protection and production.

   The extension services need extra training in the field of integrated protection and production. This could be provided partly by IOBC, through continuation and further development of its successful training courses with the EC, and through further development of the EC's European Training in Integrated Crop Protection (ETIC) network.

6. National governments and the EC should seek the means and instruments to increase the economic incentives for farmers to move from conventional to integrated crop protection and production.

   If new crop protection and production programmes do not offer clear economic advantages to farmers, implementation is hard to achieve. Farmers perceive integrated protection as knowledge intensive, time consuming and more risky.

   Incentives may consist of (1) taxes (levies) on chemical pesticides, (2) use of an integrated protection/production label, (3) extra support from the extension services.

   Quality standards for an integrated protection/production label should embrace and include quality of the production procedure. External cosmetic features should play a less important role. Preferably one European label for integrated protection/production should be developed (with assistance from IOBC wherein a great deal of experience is available).

   Another important incentive for farmers will be abolishing the zero tolerance for pests and diseases. Zero tolerance leads to extreme over-use of pesticides, no guarantee of pest- and disease-free products, and makes it virtually impossible to use environmentally safer control methods.

Implementation of integrated protection demands extra training of the farmer, partly through provision of information brochures for specific crops (a potential task for IOBC). Demonstration farms provide an excellent way to show farmers what the possibilities are and to create an opportunity to update the programmes on a continuous basis.

7. The Council of IOBC/WPRS should bring the above conclusions and recommendations to the attention of the EC and national governments and urge them to take action.

Appendix I

Examples of Integrated Pest Management as presently applied commercially in Europe

- Biological and integrated control in glasshouses, mainly vegetables (on 30% of the European glasshouse area)
- Supervised and integrated control in fruit orchards (on 15 and 7% of the European area, respectively)
- Integrated control in vineyards (on 20% of the European area)
- Supervised control in cereals (on 5% of the European area)
- Biological control of pests in maize (on <5% of the European area)
- Supervised control in vegetables (cabbage, leek, carrot etc., on <5% of the European area)
- Genetic control of onion pests (sterile male technique, on <5% of the European area)
- IPM within integrated farming systems for arable crops (exploiting beneficial interactions of all inputs: under evaluation on farms in the Netherlands and Germany)

Appendix II

List of the most important constraints to implementation of integrated crop protection, as identified by conference participants (ca. 100 returns)

1. No general policy for integrated protection and production (IPP) at the European level
2. Lack of knowledge about IPP by policy makers and politicians
3. Lack of knowledge about IPP by farmers
4. Lack of extension officers well trained in IPP
5. No economic incentives for IPP
6. Insufficient research funding for IPP
7. Unrealistically high product quality demands and unrealistic zero-tolerance
8. High costs of IPM programmes
9. IPP not clearly defined for outsiders; confusion about the standards for a labelled product
10. Lack of confidence in IPP

Appendix III

Specific tasks for IOBC/WPRS

1. Development of an IPM label
2. IOBC should "go public", making clear what IPM is, why it is needed and what the IPM label means. It should develop an ongoing publicity campaign for IPM
3. Publish available information on complete, commercially available IPM programmes in small booklets (for extension officers and farmers)
4. Continuation and further development of IOBC/EC training courses in IPM
5. Lobby EC policy makers. EC rules and guidelines can bring national governments into a common line. Assess EC policies for their impact on the environment in general, and the opportunities for IPM in particular. Define policy targets for IPM implementation, not leaving this to governments.
6. Continue to organise meetings where policy makers, extensionists and scientists meet on a regular basis

Conclusions

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Recommandations

Conclusions

1. La Conférence a réussi à unifier les intérêts de scientifiques, de décideurs politiques et de spécialistes du développement, dans le but de parvenir à une réduction significative de l'usage des pesticides en Europe par l'intensification de l'application de la lutte biologique et de la protection intégrée des cultures. De tels intérêts et efforts communs sont essentiels pour stimuler et coordonner la gestion intégrée de la lutte contre les organismes nuisibles (invertébrés, maladies, plantes adventices) dans un futur proche.

2. De quatre décennies de recherches en lutte biologique et protection intégrée, coordonnées par l'OILB/SROP, a résulté, dans certains systèmes de protection et de production des cultures, une diminution de la composante pesticides des intrants (réduction de 30 à 85 %, exceptionnellement 95 %). La faisabilité économique et écologique de plusieurs systèmes a été prouvée et ils peuvent, en conséquence, être appliqués à une bien plus grande échelle qu'à présent (voir Annexe 1 pour les exemples).

3. Certains pays européens ont récemment développé une nouvelle politique nationale de protection des cultures ayant pour but une considérable réduction des pesticides utilisés, avec pour principes de base la protection et la production intégrées. Les politiques communautaires en protection des cultures sont encore inexistantes ; le besoin en est urgent dans le but d'harmoniser les politiques nationales.

4. Une enquête auprès des participants à la conférence a révélé 10 contraintes majeures à l'application de la protection intégrée (voir Annexe 2). La vulgarisation est l'instrument clé pour appliquer les systèmes de protection et de production intégrés car ceux-ci exigent un niveau de connaissance élevé. Néanmoins, beaucoup de gouvernements ont réduit notablement les budgets consacrés à la vulgarisation par le biais d'un processus de privatisation.

Recommandations

1. La Communauté Européenne devrait, aussitôt que possible, agréer une nouvelle politique de protection des cultures basées sur les principes de protection et production intégrées. Une telle politique devrait alors formuler les règles de base communautaires en matière phytosanitaire pour l'homologation et la législation sur les pesticides.
   Pour les remarques particulières, voir les recommandations 5 et 6.

2. La communauté européenne devrait développer un programme de recherche et de vulgarisation, particulièrement sur la protection et production intégrées, dans le but d'accélérer le développement et l'application de ces méthodes respectueuses de l'environnement.

3. Les gouvernements nationaux devraient développer de nouvelles politiques nationales de protection des cultures en harmonie avec les situations spécifiques et les besoins de leur pays.

   Si la protection intégrée doit avoir un futur, alors les politiques gouvernementales de soutien à la mise en pratique des méthodes de protection des cultures respectueuses de l'environnement sont essentielles. De telles politiques devraient inclure des objectifs bien définis afin de permettre d'en mesurer les progrès. Il est important que ces politiques soient développées avant 1993 dans les pays où elles sont actuellement absentes, afin que soient évitées en pays voisins la déterrioration de la situation en matière de protection des cultures, ainsi qu'une compétition inégale.

   Les directives courantes d'homologation et de législation sur les pesticides se refèrent insuffisamment à la protection intégrée des cultures.

   Les procédures d'homologation pour les agents utilisés en lutte biologique ne sont pas claires et trop gourmandes en temps ; elles devraient être spécifiques au type d'agent biologique à homologuer. Les mesures législatives devraient être établies et déboucher sur des procédures d'homologation plus faciles et meilleur marché pour les pesticides sélectifs et les biopesticides.

   Les prélèvements financiers sur les ventes de pesticides (voir recommandation 6) devraient non seulement être considérés comme un instrument financier mais aussi comme un moyen de protection de l'environnement.

4. La réalisation d'une politique de protection des cultures respectueuse de l'environnement nécessite des recherches complémentaires et, en conséquence, l'accroissement des moyens financiers.

La recherche de méthodes biologiques de luttes spécifiques contre les insectes et les maladies devrait être encouragée et accrue. Les programmes de recherches actuels sont orientés vers la lutte contre les insectes et acariens mais il est nécessaire d'accroître les investissements pour la lutte biologique contre les maladies et mauvaises herbes plus particulièrement, ainsi que les nématodes.

Bien qu'il y ait eu plusieurs programmes de lutte intégrée menés avec succès, d'autres sont incomplets car destinés à un nombre limité d'insectes, de maladies et d'autres contraintes qu'il est nécessaire de gérer dans la culture. Ceci rend l'utilisation commerciale de tels programmes non fiable et, en conséquence, non attractive. D'autres recherches paraissent ainsi nécessaires : 1) pour intégrer les méthodes disponibles dans le schéma complet de la production d'une culture, 2) pour intégrer la lutte contre les insectes et les maladies avec les autres intrants, tels que les fertilisants, dont la réduction d'emploi est également importante. Le développement de schémas complets de production intégrée nécessite des investissements substantiels de recherche en systèmes de culture intégrés, lesquels en fin de compte, procurent le meilleur contexte pour appliquer les méthodes de protection intégrée des cultures. Ceci devrait permettre l'exploitation plus intense de méthodes de lutte complémentaires, telle que rotation culturale et résistance durable des plantes hôtes, lesquelles devraient être fortement encouragées.

5. Puisque la protection et production intégrées demandent un haut degré de connaissances, particulièrement dans sa phase initiale, les gouvernements nationaux devraient accroître les budgets destinés aux activités de vulgarisation et de service afin que l'efficacité de cet instrument essentiel en protection et production intégrées puisse être améliorée.

   La tendance manifestée en Europe, de réduire les services de vulgarisation nationaux, interfère négativement avec la nécessité d'augmenter l'effort d'introduction de la protection et production intégrées.

   Les services de vulgarisation exigent des formations supplémentaires dans le domaine de la protection et production intégrées. Ceci pourrait être partiellement réalisé par l'OILB, par la continuité et le développement accru des cours de formation réussis conjointement avec la communauté européenne (CE) et par un développement plus poussé du réseau Européen de Formation en Protection des Cultures (ETIC).

6. Les gouvernements nationaux et la Communauté Européenne (CE) devront rechercher les moyens et les instruments nécessaires à l'accroissement des mesures économiques qui incitent les agriculteurs à passer de méthodes de protection et production conventionnelles à des méthodes intégrées.

   Si les programmes nouveaux de protection et de production des cultures n'offrent pas d'avantages clairs aux agriculteurs, leur application sera difficile. Les agriculteurs perçoivent la protection intégrée comme nécessitant beaucoup de connaissance, un investissement en temps et plus risquée.

L'incitation peut consister en : 1) taxes sur les pesticides chimiques, 2) utilisation d'un label protection/production intégrées, 3) aide complémentaire de services de vulgarisation.

Les standards de qualité pour un label de protection et production intégrées devraient couvrir et inclure la qualité du processus de production. Les caractères externes de qualité devraient jouer un rôle moindre. De préférence un label Européen pour la protection et production intégrée devrait être développé (avec l'assistance de l'OILB qui détient une grande expérience disponible).

Une autre mesure incitative importante pour les agriculteurs devrait être l'abolition du zéro de tolérance en ce qui concerne les insectes et les maladies. Le zéro de tolérance conduit à l'usage extrême des pesticides, à aucune garantie d'une production sans insectes et maladies, et rend virtuellement impossible l'utilisation de méthodes de lutte respectueuses de l'environnement.

L'application de la protection intégrée exige un supplément de formation des agriculteurs, en partie fourni par des brochures d'information par culture (une tâche potentielle pour l'OILB/SROP). Les fermes modèles sont d'excellents moyens d'exposer aux agriculteurs les possibilités existantes et de permettre une mise à jour permanente des programmes.

7. Le conseil de l'OILB/SROP se doit de porter les conclusions et recommandations ci-dessus à l'attention de la communauté européenne (CE) et des gouvernements nationaux et il se doit de les exhorter à agir dans ce sens.

Annexe I

Exemples de gestion de protections des cultures actuellement appliquées commercialement en Europe

- Lutte biologique et intégrée en serres, principalement en cultures légumières (sur 30 % des cultures sous serres européennes).
- Lutte dirigée et intégrée en cultures fruitières (sur 15 et 7 % des cultures européennes, respectivement).
- Lutte intégrée en vignoble (sur 20 % du vignoble européen).
- Lutte dirigée en cultures céréalières (sur 5 % des cultures européennes).
- Lutte biologique contre les insectes du maïs (sur moins de 5 % des cultures européennes).
- Lutte dirigée en cultures légumières (chou, poireau, carotte, etc... sur moins de 5 % des cultures européennes).
- Lutte génétique des insectes de l'oignon (techniques des mâles stériles, sur moins de 5 % des surfaces européennes).
- Gestion intégrée de la protection dans les systèmes de gestion intégrée des cultures (exploitation des interactions bénéficiant de tous les intrants : en cours d'évaluation sur des exploitations en Pays-Bas et Allemagne).

Annexe II

Liste des contraintes majeures à l'application de la protection intégrée des cultures, telles qu'elles ont été perçues par les participants à la conférence (environ 100 réponses)

1. Pas de politique générale pour la protection intégrée des plantes au niveau européen.
2. Manque de connaissance de la protection intégrée des plantes par les décideurs politiques et les politiciens.
3. Manque de connaissance de la protection intégrée des plantes par les agriculteurs.
4. Manque d'agent de développement bien formés en protection intégrée des plantes.
5. Absence de mesures économiques incitatives pour la protection intégrée des plantes.
6. Financement insuffisant des recherches en protection intégrée.
7. Demandes irréalistes d'une qualité de production avec zéro de tolérance de présence d'organismes nuisibles.
8. Coûts élevés des programmes sur la production intégrée.
9. Définition peu claire de la protection intégrée des plantes pour le profane ; confusion sur les normes pour un label de production.
10. Manque de confiance dans la protection intégrée des cultures.

Annexe III

Missions spécifiques pour l'OILB/SROP

1. Développement d'un label Production intégrée.
2. L'OILB/SROP se doit, de mettre la production intégrée à la portée du public, de lui préciser quelles sont ses définitions, ses exigences et ce que signifie le label Production intégrée. Elle se doit de développer une campagne permanente en faveur de la production intégrée.
3. Elle se doit de publier l'information complète disponible sur les programmes de production intégrée en petites brochures (pour les agents de vulgarisation et les agriculteurs).
4. Elle se doit de continuer de développer les cours de formation conjoints OILB/CE sur la production intégrée.
5. Elle se doit - d'être en contact avec les décideurs politiques de la C.E. car les règles et directives de la C.E. peuvent conduire les gouvernements nationaux à suivre une ligne de conduite convergente - d'évaluer les politiques de C.E. d'une part pour leur impact sur l'environnement en général et, en particulier, pour les facilités assurées à la protection intégrée des plantes - de définir les objectifs politiques pour les applications de la protection et production intégrées, ce qui ne doit pas être du ressort des gouvernements.
6. Elle se doit de poursuivre l'organisation de réunions où les décideurs politiques, les agents du développement et les scientifiques se rencontreront régulièrement.

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