SESSION 9A

PESTICIDE LEGISLATION – RECENT INTERNATIONAL TRENDS AND PROBLEMS OF IMPLEMENTATION

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INVITED PAPERS 9A-1 to 9A-4

INTERNATIONAL PESTICIDE REGISTRATION - AN OVERVIEW

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ABSTRACT

International regulations controlling the introduction and use of pesticides continue to increase in their complexity. Prospects for the international harmonisation of regulations appear to be receding. Mis-understanding and mis-representation of the risks associated with modern pesticides has arguably led to over-regulation and the delay of the entry of such products to the market place.

INTRODUCTION

In the last few years the regulatory requirements associated with the introduction of new pesticides have witnessed considerable change. Such changes, to an extent, mirror regulations introduced in other areas of invention such as pharmaceuticals, or indeed reflect general safety concerns for housing and motor vehicle construction. Whilst the need for regulation and restriction is readily understood in order to meet the needs of a society requiring benefits at low risk, it can be argued that in the case of pesticides, certain requirements may be excessive and lacking in sound judgement on the part of regulators, thereby either denying or retarding the entry on to the market place of products whose profile clearly marks an advance in terms of efficacy and safety.

The need for pesticides to play a role in maintaining food production and also in controlling vectors of disease, whilst disputed by a few, cannot be reasonably denied in a global context. Famine, drought and disease remain ever present in the wings and without man's intervention and indeed, in many instances, despite it, can harbour economic and human problems on a significant scale.

Balances need to be sought in order to rationalise the procedures whereby new products may play their useful role without bureaucracy intervening between sound scientific judgement and the market place.

PERCEPTION AND REALITY OF RISK

There appears to be a view of increasing currency that pesticides are firstly unnecessary and, secondly, harmful to man and to the environment. For those who subscribe to such a position, the matter is no longer one of debate, but one requiring action. The reasons for arriving at such a viewpoint are complex and even for those who would argue against them, not without validity. Part of the issue reflects concern for the unknown of which "chemicals" represent a particular evil because certain examples of them have unquestionably been shown to be toxic in one form or another. Industrial disasters such as Bhopal, whether pesticide-related or not, add fuel to those who have a view that pesticides may represent an insidious global threat. The simplistic view is often expressed that as pesticides are meant to kill, therefore they clearly have the capacity to produce environmental and human health risks.

Without entering into a debate on this particular issue, it is nevertheless apparent that perspectives on pesticide safety have become blurred, and industry, certainly in retrospect, has not always presented proper explanation in order to provide an objective balance. For example, it is clear from the work of Ames and others that both man-made and naturally occurring chemicals have similar potentials for risk and that many constituents of 'natural' diet are mutagens and carcinogens. These are frequently present in quantitites in excess of pesticide residues, even assuming these latter to have such adverse toxicological properties. Also in this context, the comparison between the outcome of long term toxicity studies between naturally occurring chemicals and man-made chemicals demonstrates an approximately 50% incidence of carcinogenicity in both sources of chemical. Such a finding is perhaps not entirely surprising given the protocols now required for such testing whereby compounds are expected to be dosed until the maximum tolerated dose is reached or exceeded. In the case of essentially bland compounds, this can sometimes result in the dosing of quite unreasonable amounts of chemical, stressing bio-chemical and other functions to a point where cellular change is not unexpected.

Perhaps as a reflection of the foregoing concerns, coupled with the need to preserve the environment, regulatory bodies have, by their own volition, and as a result of political pressure, extended the regulations controlling pesticides significantly in the last few years. From the standpoint of the consumer and those distanced but nevertheless concerned for these issues, such an increase in regulations may be seen to be beneficial. From an industry standpoint, however, the viewpoint is somewhat different and over-regulation seen as a barrier to product introduction.

The development programmes for a new pesticide fully recognise the need for a full and positive understanding of the toxicolgocal and environmental profile which the new entity might present. Such programmes, even discounting the cost of failures, result in expenditure in millions of pounds, with resources being employed for periods typically of seven years or more. It is, therefore, of concern to observe regulatory trends which appear to be adding to a need to satisfy chauvinistic bureaucracy rather than adding to a true understanding of risk.

HARMONISATION

Much has been spoken of harmonisation of requirements and regulations, whereby one set of data, however extensive, could satisfy the needs of several governments. To a certain extent this has become true of toxicological studies, but is not wholly so. The unification of EEC regulations in 1992 is anticipated by some as an act of wide harmonisation. The recent introduction by West Germany, Italy, Denmark and Eire of wide ranging additional and separate requirements for pesticide registration prior to such harmonisation makes it difficult to see how unity will be reached. Whatever the outcome, it seems highly likely that the procedure for clearing pesticides on to the European market in the future will be more lengthy than at present. The combination of the period required to obtain clearance, to which must be added the original development timetable, erodes substantially into the few years left of patent protection which an inventor now has for his pesticide.

The lack of harmonisation of environmental requirements is particularly noteworthy, leading to such parochialism of attitude whereby different States within the United States do not readily accept that the behaviour in, say, Californian soil necessarily applies to Arizona, This may lead, on occasion, for additional studies to be undertaken. In a global context, to take this example further, studies to determine the behaviour of pesticides in soil and water undertaken in the field in one country are rarely accepted elsewhere even though soil scientists and climatologists will adduce that the conditions of the study in question were entirely inter-territory representative.

Apart from the difficulties of harmonisation for which no immediately positive prospect is in sight, the sheltering behind "checklist" legislation can lead to unwarranted difficulties and delays. This is particularly so where requirements do not permit an overview to be taken and the result from one particular isolated requirement can delay or even destroy the regulatory process. A recent example relates to a product of such low water solubility that it was without any effect upon fish whatsoever. It was nevertheless deemed highly toxic to fish by the U.S. Environmental Protection Agency because the guideline requirement to undertake fish toxicity testing at a range of concentrations had not been fulfilled.

A further example, and company files abound with similar ones, stems from a recent requirement from Canada to undertake inhalation toxicity testing on an active ingredient of extremely low vapour pressure and the physical consistency of a thick syrup. By dint of argument and persuasion, avoidance of a bizarre, unecessary and meaningless test in animals was achieved. This latter example, which also ties in with failure of harmonisation, is particularly significant where the unnecessary use of animal experimentation is demanded. Where studies serve no useful purpose to add to information which can be readily predicted from other souces, then governments should respect this and be prepared to be pragmatic. This is unfortunately not so and in many countries regard for the unnecessary use of animals is not seen as an argument against filling a "checklist" item.

CONCLUSION

This overview has deliberately not set out to list current or prospective international regulations. These remain subject to change and are available from the national authorities, as appropriate. The purpose has been more to suggest that as a possible illfounded over-reaction to the belief that pesticides are a real threat to life, resulting regulation has in itself been over-reactive, and that the lack of harmonisation, combined with the belief that legislation rather than science will provide protection, can only result in the delay in introducing novel pesticides which can make a significant impact upon food production and health.

REGULATION OF PESTICIDES IN SWEDEN

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ABSTRACT

In 1986 a new Swedish authority, the National Chemicals Inspectorate, started its activities and a new Act and Ordinanceson chemical products became effective. According to the legislation the manufacturer or importer should carry the legal responsibility for any harm arising from the use of chemicals. The Chemicals Inspectorate states action levels and carries out inspections. For pesticides, a pre-approval system is practiced with a 5-year review time. The evaluation process contains the following steps: hazard analysis, risk analysis, benefit analysis, analysis of consequences, and risk - benefit analysis.

Swedish agricultural policy with respect to the use of pesticides is expressed in a scheme of action on how to reduce the risks for health and the environment, resulting from the agricultural use of pesticides. The governmental aim is to reduce the use of agricultural pesticides by 50 percent in 5-years time by adopting a number of special measures to this end. This scheme of action was initiated in the spring of 1986. It took one and a half years to compile the legal and scientific basis for the programme. In the next three years we will see if we have been successful.

INTRODUCTION

In 1986 a new Swedish authority for chemical control started its activities. At the same time the Act on chemical Products together with connected Ordinances entered into force.

The authority is The National Chemicals Inspectorate, and the legal instruments are following:

the Act on Chemical Products
the Ordinance on Chemical Products
the Ordinance on Pesticides
the Ordinance on the Spreading of Pesticides over Forestland
other connected ordinances.

THE AIM

The aim of the new Act is to prevent injury to human health and to the environment being caused by the inherent properties of chemical substances.

THE LIABILITY

The manufacturer or importer carries the whole legal responsibility for any harm arising from the use of a chemical introduced by any of them on the Swedish market. They are responsible for the precautions which must be undertaken in order to prevent or counteract injury to man or to the environment by way of their own investigations in terms of a risk profile taking into account the health and environmental implications imposed by the use of their chemicals.

WHAT DOES THE AUTHORITY DO?

The Chemicals Inspectorate issues regulations and general advice and states action levels in order to help manufacturers and importers to fulfill the intentions of the act. Supervision is also carried out through inspections of manufacturers and importers of chemicals.

Pesticides have to go through an investigation procedure before marketing. In 1988 there were 655 approved products containing 250 active ingredients. The Chemicals Inspectorate considers both the toxicological and ecotoxicological effects of chemicals in the evaluation, documentation and investigation process. We maintain a register on all chemical products manufactured in or imported into Sweden. 70,000 different products are currently reported. We also have close contacts with the other Nordic countries as well as with international bodies such as the OECD and UNEP.

When the Act on chemical products was presented to the Riksdag (the Swedish Parliament), the Ministry of Agriculture elaborated on the precautionary steps that should be taken when the risk of using a chemical is considered. Initially a scientifically based suspicion that a chemical may cause damage is basis enough for action according to the Act. In such cases the uncertainty that might arise from the hazard of using a certain chemical shall not be carried by the general public but shall fall upon those who want to market the product. These statements which interpret the intentions of the present Act support the restrictive attitude of the Chemicals Inspectorate towards chemicals.

The Ordinances

I would now like to say a few words about what is new in the Ordinance on pesticides. Thus:-

An approval only lasts for five years at which time it has to be reviewed again.
Aircraft spraying of pesticides is forbidden.
Classes indicating hazards have been changed to classes indicating who may use the specific pesticide. Thus:-

1. Pesticides that may only be used professionally by someone holding a special permit.
2. Pesticides that may only be used professionally.
3. Pesticides that may be used by anyone.

The documentation requirements for pesticides remain unchanged and date from 1982.

The Evaluation Procedure

The evaluation procedure comprises the following steps:-

Hazard Analysis

The assessment of the inherent properties of chemical substances and their capacity to harm man and the environment.

Any uncertainty in the documentation should be clearly expressed, such as, unsatisfactory tests not following established criteria and statistical uncertainty, such as low statistical strength. Scientific uncertainty is for example associated with the range of interpretation of an effect based on animal tests at high doses and its extrapolation to risk for humans at low doses.

Risk Analysis

The estimation of the probability of any harm occurring and its likely extent. The risk analysis considers for example:

Residues of pesticides in food

Exposure when handling a pesticide

Exposure to the environment

Nature has no protective clothing

Benefit Analysis

The assessment of possible advantages with a certain use of a chemical product, such as:

The efficacy of the pesticide

The need for the pesticide compared to existing products and also compared to other non-chemical methods (e.g. mechanical)

Analysis of Consequences

The prediction of the consequences of choosing a certain decision alternative.

Risk - Benefit Assessment

The assessment based on an acceptable risk from the standpoint of society at the time of decision. This leads to approval or rejection of the proposed use of the pesticide.

AGRICULTURAL POLICY IN SWEDEN WITH RESPECT TO THE USE OF PESTICIDES

In the spring of 1986 the Chemicals Inspectorate, together with the Board of Agriculture and the Environmental Protection Board, received the assistance of a governmental commission to prepare a scheme of action on how to reduce the risks for health and the environment, resulting from the agricultural use of pesticides. The aim was to reduce the use of 50% in five years time.

The quantity of active ingredients in agricultural pesticides sold in 1985 was 4,500 tons of which 3,500 tons were herbicides. It has been suggested to measure the use as the amount of active ingredient, and to assume the means of use from 1982 to 1985 as the basis, to allow for annual variations.

The proposals for fulfilling the programme have been divided into three main groups. Thus:-
Change to pesticides that are less toxic to health and the environment
Reduction of the use
Special measures to protect health and the environment

Reduction of the risks should be carried out in many different ways. Thus:-
To withdraw old pesticides with insufficient documentation or suspected high risks.

Stricter evaluations regarding the need for a pesticide should also be carried out. The need should always be evaluated vis-a-vis other techniques - chemical or mechanical.

Use of lower doses than originally recommended for herbicides in spring cereals. The original proposal was to test herbicides at several doses in the official trials in order to get better support for the advisory officers to contribute with differentiated advice to farmers. When the University of Agriculture went through their field trial files they found a substantial documentation supporting the best yields at half the recommended dose and at an 80% herbicidal efficacy. The fact that the best yields for the crop was obtained at half the recommended dose is probably due to the stress the crop is exposed to by the 90-95% herbicidal efficacy. The dose recommendation has of course to be differentiated in consideration of high amounts of weed, type of weed, type of soil and crop-rotation system. The advice to lower the dose in crops of spring cereals was given for the first time last spring and the results have not yet been evaluated.

Increasing the number of residue samples that are taken from food so that the risk can be better identified and taken care of.

Increasing the research programme on the persistence and leaching of chemical substances so that we improve our knowledge and get better feed back into the regulatory work concerned with approval and rejection. Thus, the rejection levels will be better founded.

Reduction of the use of pesticides is considered to be fulfilled by the introduction of standard testing of all spraying equipment. An annual conditioning testing of existing spraying equipment is also on its way to being introduced. Farmers are encouraged to get their equipment through a conditioning test with a subsidy covering 75% of the test costs. The official advisory service to farmers should be strengthened in order to provide the officers with better tools for prognoses. The use of alternatives to pesticides should be encouraged when it is economically acceptable. On the other hand, prophylactic spraying should be discouraged.

A number of special measures to protect health and the environment have been suggested. The prohibition to fill field crop sprayers directly from lakes or water courses should reduce the pollution of water by pesticides. A training and education programme for all professional agricultural sprayers will be operative in the spraying season of 1990. This is intended to increase the consciousness of the risks and there by give a safer handling.

In the table below the different suggestions have been classified together with the amount of reduction in use they are estimated to represent.

TABLE 1

Expected effects of the proposal

Proposal	Percent reduction in 5 years time compared with present use	
Use of better spraying equipment and annual conditioning control	25	
Differentiated advisory service and lowering of the doses of herbicides	10	
Withdrawal or restrictions of such pesticides that entail the highest risks	15	(The risks will be lowered as much as if the use had been reduced by 15%)
Better control of pesticide residues in food commodities		
Better education for agricultural sprayers		

The commission to prepare a scheme of action to reduce the risks was, as mentioned above, initiated in the spring of 1986. It has taken one and a half years to bring together the legal and scientific background for the programme. In the next three years we will see if we have been successful.

REFERENCES

Unfortunately, all references and background material for this paper are in Swedish. The following information on chemicals control is however, available in English.

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THE AGROCHEMICALS DISTRIBUTOR AND LEGISLATION

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ABSTRACT

The Agrochemical Distributor plays an increasingly important role in the Agricultural Industry and as such is actively involved in the wide range of legislation controlling the storage, transport, supply and use of pesticides. Whilst many of the principles of European Community Directives and National Laws on pesticides have been supported by the Distributor, there is an increasing sense of a lack of practical awareness and a more bureaucratic approach by the legislators. Against this background, and with the future implications of the Single European Act, it is imperative that the Distributor maintains an active dialogue with the legislators so as to ensure that any new legislation combines idealism with pragmatism.

INTRODUCTION

I would like to thank the British Crop Protection Council (BCPC) first of all for inviting a paper from the distribution section of the agrochemical industry and welcome in particular BCPC's greater concern on the practical world in which agrochemicals are made, supplied and used. The United Kingdom Agricultural Supply Trade Association (UKASTA), which represents a large proportion of the distribution trade, has been fully represented on BCPC for many years and rightly so.

For it is important to know that the distribution industry is not just about handing over a product from the manufacturer to the farmer or grower. It is about the best and most efficient method of distribution, and increasingly this often also means provision of a full independent counselling service in the fields of the farmer client and for some of UKASTA members, their view on formulation and packaging operation, field trials and laboratory work. One could say that the new legislation has helped promote this and has therefore performed a valuable service while continuing to recognise the traditional role of the general merchant.

It must also be added that the distributor can be a user or a commercial applier himself and many are treaters of seed, spraying contractors, fumigators of crops like cereals, potatoes and fruit, and are, of course, involved not only in agriculture, horticulture and forestry, but also in amenity and local government work and industrial pesticide control. UKASTA members supply 50% of the rodenticides used in the UK. It is therefore no surprise that when legislators throughout Europe considered introducing controls over pesticides they earmarked distributors (as well as manufacturers and users) as worthy of attention. The result is that today in most European countries, as well as The United States of America, Legislative controls exist over the basic activities of storage, transport and supply, often with additional provisions on Environmental care. The other general rules about product approval, labelling and use also apply directly or indirectly.

STORAGE, TRANSPORT, SALE AND SUPPLY

On storage legislation generally orders the following:-

1. Segregation of chemicals from human or animal products and oxidising substances such as nitrogeneous fertiliser.
2. Special treatment of toxic and very toxic substances.
3. Rules of construction and siting of stores.
4. Rules on security as concerns the public.

There are, of course, national differences. Not every country has an obligatory storage certificate which storage personnel must pass as is the case in the UK. France is one of these. In some countries small quantities of chemicals and certain chemicals themselves are exempt from legislation.

Not all have Government enforced regular inspections of stores as in the UK and France. In the UK, the Trade was responsible (and fortunate) enough to have instituted its own Storage Standard and Storekeeper Certification Scheme, the British Agrochemicals Inspection Scheme which provided the Ministry of Agriculture with a convenient instrument. Distributors retain a valid share in running this organisation. The same applies to transport with generally common rules prohibiting or severely restricting mixed loads of chemicals and particularly foodstuffs, very toxic and toxic chemicals (West Germany is severe here) and requiring appropriate documentation and warning symbols.

It is perhaps on the actual activity sale and supply that there are the greatest interstate difficulties. The British requirement that all sellers and suppliers, with certain exemptions should have to obtain a Government approved certificate is in advance of most other countries.

EUROPEAN COMMUNITY DIRECTIVES

All this national law is backed up and supplemented by the nearly forty EC Directives and decisions on pesticides issued between 1967 and the present day, fifteen of these concern classification, packaging and labelling of product, the latest ruling being issued quite recently. A general Directive on 'Trade, distribution and the professional use of toxic products', although mainly concerned with marketing and preserving the competition rules of the Treaty of Rome was published as long ago as 1974. There have been six important Directives on either the pollution of the aquatic environment or protection of the quality of drinking water, and a further two on toxic waste. Finally, you will all know of the four Directives on pesticides residues in crops of most sorts, feed stuffs and products of animal origin.

As I write this the Agricultural and Environment Directorates having finally agreed to cooperate over the environmental policy, are considering a definitive Directive having stated in a policy document in June this year that they wanted 'The use of pesticides reduced to a strict minimum' and much of this great mass of legislation may have been superceded. It should be mentioned here too, that in the Commission's eyes a distributor's agrochemicals stores must be treated the same as a manufacturer's factory - which seems rather a case of over reaction in the wake of the frightful disaster on the Rhine.

PRODUCT REGISTRATION AND APPROVAL

It must not be forgotten, too, that distributors are much affected commercially by National European requirements on registration and approval of products. We, like the British manufacturers, have been greatly and unjustly hampered by the British Government in the ability to launch its Product Review Scheme quickly and the greatly damaging effect this has on the introduction of new and often safer active ingredients and formulations. In the last two years twelve new molecules and seventeen new products have been introduced in France. Britain lags a great way behind. This must surely displease that great supporter of entrepreneurialism and initiatives in Downing Street. This problem is particularly onerous when taken with the withdrawal of and restrictions added to the approval of certain products which are the only ones in their field. The distributor is also much affected by labelling and information requirements.

THE DISTRIBUTORS' VIEW

What then is the reaction of the distributor to legislation which not only covers all his activities and more, but which seems to aim to cut down the very tool of his trade both for environmental, and now, crop production reasons. Generally it can be said that he has accepted and indeed welcomed the principles behind the legislations. This is true not only in the UK but in the other member countries of the European Union of Agrochemicals Distributors (UCEPCEE). The distributor believes in running an orderly house showing responsible care for his activities both to his customers and to the public. There is no alternative to legislation if the public wishes it and the distributor can and should show the public (and legislators and politicians) that the chemical products he uses are both necessary and safe. Chemicals will continue to be needed and the latest technology improvements in safety, target specificity, and environmental care encourage this. As a contributor the recent Agra report said the public would prefer to pay slightly more for food treated with technically more advanced products than the huge increases needed with organically grown crops (if these could provide all food needs which does not seem likely).

Government in Europe therefore have had perhaps a surprisingly high degree of acceptance of legislation by distributors just when national distributors obviously have their particular bones of contention. In the Netherlands this is reflected in the return of pesticide containers and in West Germany, storage. In the UK ours include two main issues - firstly, the great duplication of laws and rules produced by two different Ministries, namely Agriculture and Environment, the enforcement agency, i.e. the Health and Safety Executive and the main local Water and Fire Authorities. Take distributors' stores for example where it appears that any authority or agency may impose its own standards, for example, of segregation of toxic materials and water containment - even though the principal legislator the Ministry of Agriculture has created these standards and obtained Parliamentary approval. As far as labelling is concerned we have to abide by the approved products label, then the Classification, Packaging and Labelling Regulations, the new Consumer Protection Act safety information requirements for customers (including the same item as on the approved product label) and prospectively the Controls of Substances Hazardous to Health Regulations.

Secondly, in apparent contradiction to this ever growing 'Topsy' of standardisation, there seems an in-built aversion to the British Civil Servant (perhaps it is part of his natural make-up) to define and clarify legislation when this is needed on the ground. The new Pesticides Residues Regulations are an example. Liability is left where it falls with an inadequate definition where sampling should take place, leaving the various links in the food chain - with, of course, their expensive lawyers to squabble over the burden of truth. Already insurance premiums on agrochemicals policies have risen by some 30% since the introduction of the new legislation.

Without being over exact and retaining flexibility Whitehall must, the UK distributors suggest, be more aware of how things work out in practice. The Ministry of Agriculture was only rescued, I would suggest, from its ill thought out (and mainly political) announcement on the withdrawal and disposal of dinoseb by the responsible cooperation of distributors, manufacturers, contractors and farmers. However, things do seem to be turning out better in this respect.

THE FUTURE

So with the approach of the magic date of 1992 when the different European legislative controls have to be all brought into line, how does the distributor view the future as far as regulations are concerned? If the rules are clear, combine idealism with pragmatism and are based as far as possible on fact and arrived at as far as possible with consultation with him, the distributor will be happy. The controls will raise standards, force out the unprofessional and will even stabilise the market.

Matters will be harder if such, and non factually based political, crazes suddenly take hold although these obviously have to be met and the alert distributor should anyway be prepared to widen his marketing activities.

Perhaps the hardest of all could be the imposition of a huge, unyielding bureaucracy whose life would be considerably more long lasting than any political flavour of the month.

As it is at present distributors much appreciate the opportunities for consultation provided by legislators and see the continuation of this as of the greatest importance for the future of agriculture in Europe.

THE GIFAP EDUCATION AND TRAINING PROGRAMME

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ABSTRACT

The Polytechnic Wolverhampton were engaged as consultants by the International Group of National Agrochemicals Industry Associations, GIFAP, to investigate the need for training small farmers in the safe and effective use of pesticides. Based on recommendations from a preliminary study, The Polytechnic developed for GIFAP training courses on the Train the Trainer principle. These are designed to meet the needs of potential trainers of small farmers and agrochemical retailers. The courses, which are on a learning by doing principle, have been field tested in wide spread of developing countries and Trainer Manuals are now available. A video is also available to support the programme.

INTRODUCTION

In recent times legislative controls on the use of pesticides have increased sharply. In some cases this has resulted in certain products being withdrawn from use or at least restricted to a limited range of applications. As this has often hastened the introduction of products which are considered to be less toxic, it must be welcomed. In cases involving a single product it does appear appropriate to use legislation to remove the problem however, further investigation will sometimes reveal that while the specific product related problem has been cleanly excised the underlying cause may still remain, i.e. the small farmer who has not changed his practices or attitudes to the use of pesticides.

Closer examination, particularly of small farmer practices in developing countries often reveals the following problems; incorrect dosage rates, failure to comply with recommended preharvest withholding periods, not having suitable personal protection when mixing and applying products, careless disposal and storing products in inappropriate places or containers. These examples suggest that in some cases, problems stem less from the product than from the way it is used (or misused). A closer look at legislation suggests that much tends to be reactive with some products being withdrawn as a result of bad practice in the areas mentioned above.

In such cases legislation is an easy way out and self perpetuating as in time, another product will replicate the original problem and result in the same palliative response.

Another example of the negative effects of legislation is illustrated in a recent letter to the Editor of Agro-chemicals News in Brief (Bourke, 1988). The correspondent raises the issue of current legislation on label layout and content for pesticide containers and poses the question 'who is the label for?' He comments that in his region (South Pacific) that 'the small farmer upon seeing the information presented is left so confused, bewildered and overwhelmed that he chooses to ignore all or part(s) of the label'. The author's field experience endorses this view and confirms that for large numbers of small farmers in many third world countries the label does not play a primary, or in some cases, any role in providing practical information and guidance on product use and application.

It would seem that in the case of labels the legislators and experts have lost sight of their purpose. Legislation demands that pesticides are sold with a label for the guidance of the end user. It also requires that various legal statements, standard phrases, serial numbers and many other administrative details be included. This results in little space being left for advice on product use and where two and even three languages are required on the same label the information, particularly on small packs, is so cramped and small that it is practically useless.

However, the legislators cannot carry all the responsibility as many of the experts who write the instructions for use are equally guilty of missing the target and providing information in a form guaranteed to confuse. An example found recently on a label of a pack for small farmer use instructed:-

'apply 2500-3500 ppm=0.98 cm^3 per litre or 1.40-1.96 litres per 53 gallons (200 litres)'

In practical terms the only useful information is the dilution rate, but even with its mathematically implied precision, no guidance on what criteria might be used to make the choice between the two limits is given. Field experience suggests that farmers, in the absence of specific guidance in such cases invariably use the highest rate indicated.

Few would disagree that legislation has a positive role to play in ensuring the safe and effective use of pesticides. However it is also clear that legislation cannot cure the underlying causes of misuse and it is in this area that we must educate rather than legislate. An extensive and well co-ordinated education programme might even bring about a reduction in the legislation programme. However we must not only aim to change the attitudes and practices of the small farmer but also, those who are currently providers of his advice and guidance.

THE F.A.O CODE OF CONDUCT AND GIFAP

The F.A.O. Code of Conduct on the Distribution and Use of Pesticides (FAO, 1986) requires:

That Governments and the Agrochemical Industry promote safe use practices (Article 1.3) and co-operate in the diffusion of education material (Article 3.6).

That the Industry ensures the proper training of personnel involved in the sale and distribution (Article 8.1.9) and in the promotion of pesticides. (Article 11.1.16).

That Industry maintain an active interest in following its products through to the end user. (Article 3.4.4).

GIFAP, as the voice of the Agrochemical Industry has as its primary objective the safe and effective use of pesticides. In pursuing this objective GIFAP and its member National Associations have agreed to abide by the Code of Conduct and already provide a series of Guidelines booklets on distribution, transport, safe use, waste disposal and emergency measures in the case of poisoning.

In early 1986 GIFAP set up a Working Group to investigate ways in which it could take a training initiative to be targeted at the small farmer in developing countries. The Group invited The Agricultural Education and Training Unit of Wolverhampton Polytechnic to make a study, as the Unit had extensive experience of agricultural and pesticide training in developing countries. The study was to investigate current use of pesticides by small farmers in developing countries and to recommend to GIFAP a generic training programme based on the findings. The study was conducted in Peru, Columbia, Indonesia, Thailand, Zambia and Cameroon. These six countries were chosen as being representative of the larger international picture.

FINDINGS OF THE STUDY

The findings of the study were as follows:-

The small farmer did not apply pesticides efficiently and safely and he relied almost exclusively on the agricultural retailer for advice. The quality of some of this advice was often suspect as a high proportion of retailer staff had the same difficulties with label interpretation as the farmer.

The majority of leaflets and brochures available were considered difficult to understand.

Storage of pesticides tended to improve with scale of operation, the smaller and poorer farmers stored pesticides in the house, this being the only secure storage area available.

Most farmers were more aware of the oral than dermal dangers of pesticides.

Disposal of surplus spray mixture was usually achieved by double spraying a section of crop and few farmers were guilty of disposal into waterways and drainage lines.

Container disposal seemed to be related to the utility or commercial value of the container and in general the practice of burning or burying containers was not followed.

Few small farmers used any form of protective clothing and even in the rare cases where retailers kept stocks, sales were minimal.

The knapsack sprayer, which is the most common applicator, also contributed to field based problems. As well as the hazard of leaks, the field use of this piece of equipment is poorly practised and understood. This point is reinforced in a recent FAO Report (FAO 1985).

The extension worker is inadequately trained and informed to give farmers appropriate advice on the field problems encountered.

OUTCOME OF STUDY

Three major sources of farmer information and advice were identified. These were pesticide labels and brochures, the pesticide retailer and the extension worker. However, it was clear from the study that the farmer was not being supplied with advice which was readily understood and relevant to his conditions and that most information was concerned with 'what to do' rather than 'how to do'.

It was decided that the most effective way to help the small farmer was to develop a training programme which could improve the quality of information and advice received through these three identified sources. From previous experience, it was known that farmers would respond favourably to training which demonstrated how they could make best use of pesticides in their own environment and 'efficient use and application of pesticides' could provide the Trojan Horse in which safety training could be introduced. However, the messages delivered would have to genuinely address the existing field problems, and provide practical solutions to the problem of protective clothing and field practice.

THE GIFAP EDUCATION AND TRAINING PROGRAMME

In developing the programme GIFAP specified that it should be designed so that it could complement, rather than compete with, existing systems and initiatives. Using the three targets previously identified it was decided to develop:

a booklet in the GIFAP Guidelines Series for writers so that they can make their material more readily understood by farmers,

a course for retailers which would improve the quality of their advice to farmers. The course content would be detailed in a training manual which would also provide guidance on how to train company agronomists to run retailer courses and

a course for the trainers of farmers who, in the main would be extension field staff. Similarly the course content would be detailed in a course manual. The manual would also contain a generic model for a farmer training course which would be developed and delivered as part of the total course. The course manual would have the additional support of a video which would demonstrate through live sequences, shot during the pilot courses, how the course should be conducted.

The basic concept was that the focus should at all times be on the farmer and how he could be assisted and motivated to use pesticides more safely and efficiently. It was also essential that the course should be predominantly practical with teaching being done through practical example and individual experience rather than theoretical lectures. To ensure the practical involvement of the individual, numbers would be limited to twelve trainers and fifteen retailers or farmers on any one course. It was also the intention that by training trainers, and giving them the confidence and enthusiasm to undertake further retailer or farmer courses, a significant multiplier effect would be achieved.

The course manuals should be comprehensive and provide detailed guidance on course organisation, planning and training strategies to be adopted. Each training session would be presented as sets of model training notes which gave objectives, detailed suggestions on training methods and full technical guidance on the pesticide topics to be covered. The manuals would also be structured to allow modifications, around a core group of subjects, to suit local needs and conditions.

COURSE DEVELOPMENT

Following the preparation of draft course manuals a series of pilot courses were organised. The retailers course was piloted in Peru, Thailand and Kenya and the farmers course in Mexico, Kenya and Pakistan. From the experiences gained the final manuals were prepared. These are now available from GIFAP with English, French or Spanish text.

The video film was shot during the pilot farmer courses and it is now also available to support the farmer trainers manual with visual demonstrations on how the various techniques and activities in the manual are translated into practical training.

THE RETAILERS AND FARMER TRAINERS' COURSES

Both these courses have been designed in two parts. The first part is a "Train the Trainer' section intended to prepare the trainers to conduct a training course for retailers or farmers. The training concentrates on developing training skills and improving pesticide knowledge and skills through demonstrations and field based practice. In the second part, having prepared thoroughly, the trainers then teach a group of retailers or farmers in accordance with the instruction given in the appropriate manual.

The combining of these two parts puts the trainers in a live training situation from day one and this greatly heightens their level of commitment and motivation. This approach has the advantage that the course tutor can be on hand to give moral and practical assistance with any problems which may arise. A further factor in using 'real' retailers and farmers is that the trainers are keen to ensure that the technical content of their sessions is accurate and appropriate. If it is not the case they then face the criticism of the group they are teaching.

Many of the company and extension staff who will be training the retailers and farmers often perceive the level of technical content in the courses as being very low and even beneath their dignity. They are also in many cases out of touch with the practical field problems of the target groups. By having the experience of teaching a real target group, they very soon become aware of the need to know how to do, as well as what to do.

The pilot courses have demonstrated that this approach works extremely effectively and the trainers leave with a much greater degree of self confidence in dealing with practical field problems. With greater self confidence the trainer can communicate more effectively with the target groups and is well prepared to run further courses in the future. Such a cycle is, with a little encouragement, self generating.

Course Tutors

By running a series of regional courses which are tutored by staff from Wolverhampton, GIFAP are developing a core resource of experienced tutors in each region. These tutors are then in a position with the guidance of the appropriate manual to run courses for trainers-in-country. This activity demonstrates the multiplier effect within the programme. As part of their commitment, GIFAP, will continue to offer assistance to those wishing to take a training initiative using the GIFAP materials.

The course for trainer of retailers

The course runs over a period of 5 days with the trainers, under the guidance of the tutor, spending the first two days preparing to teach the retailers on the subsequent three days. A maximum of twelve trainer farmers and fifteen retailers are advised for the course. The twelve trainers normally work in groups of two or three. A maximum of fifteen retailers is recommended to ensure that the practical participatory nature of the course can be maintained.

The training manual provides full advice on pre-course preparation so that all the resources can be in place when the group assembles. An Agricultural Institute or small hotel in a farming community will usually provide a suitable venue. Easy access to a local farm for field practice sessions is essential. During the first two days the trainers rehearse the training techniques specified in the manual. In preparing for their training sessions trainers gather samples of products used locally, examples of local pests and diseases and examples of knapsack sprayers. This ensures that the course content is accurately matched to the local conditions and that the course content is relevant.

The first interactive session encourages the retailers, working in groups, to identify the key problems encountered in the safe and effective use of pesticides in their area. Priorities are agreed and these are referred to throughout the course. Subsequent sessions are a mix of classroom and practical sessions. The informal and practical nature of the course encourages discussion and interchange and trainers are expected to adopt a flexible approach to the programme. The course finishes with a practical application session on a pre-selected farm. In pilot courses retailers have indicated that this session greatly improved their appreciation of the field problems of application and gave them a greater understanding of the type of information needed by farmers.

After the close of the retailers course the trainers review their work and suggest improvements. Following this initial training, the trainers are ready to run three day retailer courses, in small teams of two or three, which allows one person to prepare while the other is training.

The Farmer Trainers' Course

This course runs over a period of two weeks. The first six days is the 'Train the Trainer' period. This is followed by three days of field based farmer training. The final day is used to review and evaluate the course and decide on future programmes of farmer training.

The longer 'Train the Trainer' period is required to meet the different needs of these trainers. In the retailers course the content is relatively well defined as the retailer works within an industry lead system where there are established practices and legislation relating to the sale of pesticides. The small farmer presents a rather different problem. There is little legislation which relates directly to the way the small farmer uses pesticides and even if there was, it would be impossible to enforce. Extension services are, with few exceptions, less effective than they could be and their field staff lack training and experience in practical field skills. The range of crops and farming systems and methods used make the prescription of a standard training course more difficult. The farmer trainers course has therefore to produce trainers who can provide a wider set of training responses and also be able to motivate change without the benefit of legislative pressure or collective identity.

The number of trainers is limited to twelve. They are, for the duration of the course, formed into three 'training teams' with four trainers in each team. Each training team has responsibility for running a three day course on the safe and effective use of pesticides to a group of fifteen local farmers. The trainers are recruited mainly from extension departments but a small number of company staff are encouraged as they can contribute up-to-date pesticide knowledge and also further strengthen industry/public sector links for future co-operation in farmer training.

As with the retailers course, two experienced tutors use the course manual to guide the delivery of a series of training sessions covering, planning, practical training skills, design and use of visual aids and how to conduct effective field based farmer training sessions. Paralleled with these sessions are practical workshops and field sessions on pesticide use and application which are designed to ensure that the trainers are fully competent in the safety and technical aspects of pesticide use.

In preparing the farmer training sessions, each training team is allocated a previously identified leader farmer on whose farm the farmer training course is usually held. With this farmer's assistance the group recruits fifteen farmers who will attend the course. The farm visits are vital in establishing a good relationship with the farmers and also allow the group to assess the local training need and how it may be best met.

The farmer courses are practical in nature with farmers being actively encouraged to participate in the practical sessions which follow each demonstration. Core sessions cover; understanding the label, simple calibration, storage and disposal, dosage rates, mixing, application techniques and the use and maintenance of the knapsack sprayer. Throughout the course safety is continually emphasised and simple and practical methods to improve safety are demonstrated.

The final day of the course is used to review the course and discuss how the trainers may continue the farmer training programme in the area.

CONCLUSION

The development of the GIFAP Programme represents a major initiative by Industry in the spirit of the FAO Code of Conduct. Pilot and subsequent regional courses have demonstrated that they are well received and the technical content is appropriate. It is now up to Industry, Governments and International Agencies to ensure that the small farmer benefits from this initiative.

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SESSION 9B

STRATEGIES TO COMBAT FUNGICIDE AND INSECTICIDE RESISTANCE

CHAIRMAN	DR J. T. FLETCHER	
SESSION ORGANISER	MR M. WADE	
INVITED PAPERS		9B-1 to 9B-4

INSECTICIDE RESISTANCE MANAGEMENT : BRINGING IT ALL TOGETHER

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ABSTRACT

This paper aims to identify those factors critical to the successful implementation of insecticide resistance management programmes, and to review the role that the agrochemical industry has played in pulling together the components of success. Reference is made throughout to the example of pyrethroid resistance in Heliothis spp (the cotton bollworm complex). Industry involvement in the fields of resistance monitoring, detection methodology, mechanisms and heritability of resistance, educational programmes and developing collaborative approaches within and outwith the industry are discussed. Consideration is given to the effectiveness of industry contributions to resistance management and to ways in which these contributions should be developed.

INTRODUCTION

There should by now be little doubt that the agrochemical industry takes the threat of resistance very seriously. The rationale behind this concern has been displayed many times (Davies 1984, Dittrich 1981, Jackson 1986 & 1988, Ruscoe 1984 & 1987, Voss 1984 & 1987) and need not be reiterated here. Nevertheless, acknowledgement of the need for resistance management is not synonymous with achieving it in areas where action is warranted.

The objective of this paper is to identify those factors critical to successful implementation of insecticide resistance management strategies, and to review the role that the agrochemical industry has played in pulling together the components of success. In making this review, I shall draw heavily on the example of pyrethroid resistance in Heliothis spp (the cotton bollworm complex) because (i) it remains as one of the most serious economic threats posed by resistance to the agricultural community worldwide, and (ii) since resistance first developed in Australia in 1983, there have been a growing number of similar instances which have all involved responses from the agrochemical industry.

As we shall see, progress over the last two years in terms of co-ordinating industry-wide efforts in support of insecticide resistance management has been excellent. This is not however a signal for complacency, and I will conclude the paper with a personal perspective of what needs to be done to build upon current success.

TURNING THEORY INTO PRACTICE

The literature abounds with theoretical considerations as to how best to manage insecticide resistance (eg Comins 1984, Curtis 1985, Georghiou 1983, Georghiou & Taylor 1977, Mani 1985) and the value of this work in directing research towards practical resistance management strategies should not be under-estimated. Nevertheless, in most instances where it has been necessary to implement resistance management strategies for Heliothis spp in cotton, the choice of a strategy has been largely empirical: due to the lack of knowledge necessary to test the assumptions underlying the simple mathematical models.

In practice, the definition of a technically sound management strategy has proven relatively simple compared with the task of implementing such a strategy in the field. Experience from Australia (Forrester & Cahill 1987), Thailand (Collins 1986), Turkey and more recently the USA and Colombia has taught us that the successful implementation of management tactics is most likely to occur when the following conditions are satisfied:

i Resistance threatens the economic fabric of a state or country; especially where there have already been well-documented failures through resistance, preferably very serious in order to convince all parties of the need for a strategy.
ii There is a good entomological infrastructure to formulate, introduce, supervise and (where applicable) enforce the strategy.
iii The distribution and sale of agrochemicals can be controlled by either the private or public sector.
iv All parties are prepared to abide by the measures to ensure the continued efficacy of control programmes.

Sawicki & Denholm (1987)

Thus successful resistance management relies on two basic factors: getting the strategy right, and creating an appropriate environment to ensure its implementation in the field. What facts do we need to know, and what process must be adopted, in order to achieve these objectives?

Basic information

In order to measure the true extent of resistance in the field, appropriate monitoring methodology needs to be developed and then applied in the field. Technically sound management strategies will also require information on the mechanisms of resistance, its heritability and patterns of cross-resistance to other toxicant groups. Accurate information is also needed concerning the biology and population dynamics of the target pest, including aspects such as alternate host crops, migration and relative fitness of resistant and susceptible insects.

Validation of management tactics

This can take the form of large-scale pilot management schemes, or the monitoring of resistance before and after the implementation of a management strategy. Determining causality for observed changes under such circumstances is fraught with difficulty, nevertheless such monitoring can lead to a fine-tuning of strategies, as has been the case in Australia (Forrester, pers.comm.).

Implementation of management strategies

The key to implementation is co-operation: technical co-operation within the agrochemical industry, and between the industry, governments, consultants, extension workers and growers. Co-operation is most likely to be achieved where common interests can be established; as with eg the pyrethroid manufacturers facing resistance to Heliothis spp. However, in the case of Heliothis spp control in cotton, it is widely acknowledged that there are few viable alternatives to the pyrethroids. Most companies recognise their interdependence on each other's products in maintaining the viability of cotton pest control long-term, despite their need to compete in the market place. Even so, agreement can only be reached between all parties if debate is centred around an independent, credible database.

Carrying co-operation from the level of government institutions and the agrochemical industry to the farmer is of paramount importance and will involve a process of education. It is often the case that a cotton grower will be asked to forsake the cheap and (on his farm) effective pyrethroids in favour of relatively expensive and often mediocre alternatives in order to maintain an area-wide management programme. This farmer must be given compelling evidence to convince him that the threat of resistance is real enough to warrant the cost of taking action against it. Such a programme of education requires a vehicle; that vehicle is the infrastructure of the cotton industry, which must be effective to deliver the message. This is true whether resistance management is achieved on a voluntary basis, or through legislation which needs to be policed.

PROGRESS TOWARDS INSECTICIDE RESISTANCE MANAGEMENT

Having defined those factors critical to the successful implementation of resistance management, I would like to review the progress which the agrochemical industry has made, particularly over the last two years, towards combatting resistance to the pyrethroids in Heliothis spp.

Inter-company technical co-operation

As described by Ruscoe (1987), "the 1970's saw an increasing recognition by the agrochemical industry of its key role and responsibility to the agricultural community: to maintain and improve, in the short and longer terms, the critical contribution by pesticides to agricultural production". It was this attitude which fostered the creation of two key work groups through which most of the industry's contribution to insecticide resistance management have been channelled:

i The Pyrethroid Efficacy Group (PEG) founded in 1979, and
ii The Insecticide Resistance Action Committee (IRAC) founded in 1984.

The key roles played by PEG are (i) to establish the true facts about field failure of products as caused by resistance, (ii) to assist governments in developing strategies for dealing with the resistance problem in pyrethroid, and (iii) to improve understanding between all the partners in agriculture - governments, growers and industry (Jackson 1986).

IRAC's role, which parallels that of GIFAP's Fungicide Resistance Action Committee (FRAC), founded in 1981; is to:

i Provide expert advice to GIFAP on all technical and scientific matters relating to insecticide and acaricide resistance.
ii Develop relationships with non-industrial researchers in the field of insecticide resistance.
iii Advise and assist GIFAP in preparing and presenting an industry view on resistance.
iv Co-ordinate industry efforts to prolong the life of insecticides and acaricides by defining and recommending appropriate technical strategies to combat resistance.

Voss (1984)

Acknowledging the inter-related remits of PEG and IRAC, and the need for national resistance action committees, 1985 saw the incorporation of PEG and a number of national committees into the IRAC structure as independent sub-committees.

1985 also heralded the first warning signs of a developing resistance problem in Heliothis virescens in the USA. In 1986, these fears were confirmed with field control failures in parts of Texas and the Mississippi Delta. Clearly, concerted action from the agrochemical industry was required and in January 1987, at the Beltwide Cotton Conference, the chairman of PEG called upon his US colleagues to form a national committee, PEG-US, to co-ordinate their efforts. The workgroup, comprising of representatives from DuPont, FMC, ICI, Hoechst-Roussel Agrivet and Mobay, has made a rapid and significant contribution to the management of H.virescens in the USA.

By the end of 1987, it was clear to the rest of the world that in Australia the requirement had been for total insecticide management in cotton, not simply pyrethroid resistance management. Restrictions on the pyrethroids and the relatively high prices of many alternative products had led to heavy reliance on endosulfan early-season. With a previous history of endosulfan resistance and evidence of increasing resistance levels, it was perceived that continued success in controlling Heliothis armigera would rely on achieving a fine balance between three toxicant groups: pyrethroids, endosulfan and the rest.

This perception led PEG once again to call upon representatives in the US industry, and in June 1988 in London, a gathering of thirteen agrochemical companies endorsed a proposal calling for the involvement of non pyrethroid manufacturers in helping to combat insecticide resistance in US cotton. This collaborative effort between pyrethroid and non-pyrethroid manufacturers in tackling a practical field resistance problem is a significant development in the evolution of industry workgroups, and bodes well for the future.

Establishing the facts

Georghiou & Mellon (1983) record at least 428 species of arthropod as having developed resistance to pesticides. However, little distinction is made between changes of susceptibility in the laboratory and resistance causing economic control failure in the field. In seeking to clarify this situation, IRAC instigated a global survey of insecticide resistance, having first defined the phenomenon in a way which relates to the farmers' perception of the problem.

For the term "resistant" to be attributable to a pest/product relationship, the following criteria have to be met:

- The product for which resistance is being claimed carries a use recommendation against the particular pest mentioned, and has a history of successful performance.

- Product failure is not a consequence of incorrect storage, dilution, or application, and is not due to unusual climatic or environmental conditions.

- The recommended dosages fail to suppress the pest population below the level of economic threshold.

- Failure in control is due to a heritable change in susceptibility of the pest population to the product.

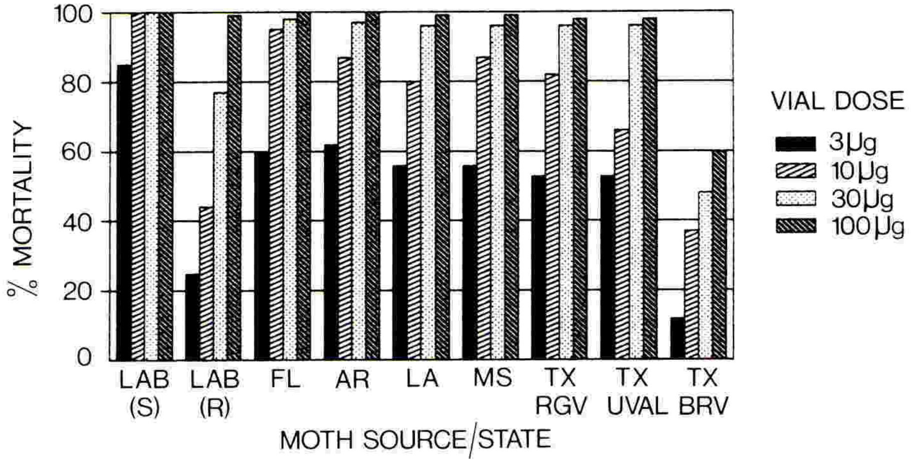
Voss (1988)

The IRAC 1984/5 survey, which was conducted on the basis of seven crop sector workgroups, identified a number of cases of resistance ranked on the basis of severity (Voss 1988). In this way, the survey fulfilled an important aim in helping to define priority cases for future research and industry involvement. In the case of cotton, three genera were highlighted as serious cases of resistance; Heliothis spp in Australia, Turkey and Thailand for pyrethroids, Spodoptera spp in Central America and Mexico for chlorinated hydrocarbons, organophosphates and carbamates and Bemisia tabaci in the Sudan, Turkey, Central America and Mexico for organophosphates and carbamates. In the case of pyrethroids, significant field resistance has subsequently developed in H.virescens in the USA and Colombia (Collins unpublished, Riley 1988).

PEG has a long history of involvement with monitoring pyrethroid susceptibility, particularly with Heliothis spp in cotton. Early studies were made in Thailand and Turkey in 1984/5. Data from Colombia on H.virescens, originally collected by individual companies, are now being collated through PEG. However, the most significant contribution to a nation-wide monitoring survey comes from the PEG-US group. In their first year of activity, the group was able to mount and co-ordinate a season-long monitoring programme across the US cotton belt. In all, over 41,000 insects were assayed from 10 states, confirming a geographic pattern of resistance which was broadly correlated with control problems in the field (Collins et al 1988, Riley 1988, Simonet et al 1988; Staetz et al 1988). The most resistant insects were found to come from parts of Texas and the Mississippi Delta, whereas Heliothis virescens from the South East remained susceptible to the pyrethroids (Fig 1).

FIGURE 1

PEG-US monitoring programme. Results for the adult vial test, 1987.



These findings enabled the pyrethroid manufacturers to speak with one voice and from a common viewpoint, and to produce guidelines for the management of pyrethroid resistance in US Heliothis spp.

During 1988, the monitoring programme has been expanded in size. Perhaps more significantly, it has also been expanded in the sense that this year's study is a collaboration between the industry and the university researchers, extensionists and cotton consultants, with PEG-US providing treated bioassay vials and collating data, whilst their non-industry co-operators collect and bioassay the test insects.

Developing unified methodology

Reaching a consensus of opinion with respect to the facts of insecticide resistance has been plagued by the use of differing methodology to detect resistance. Even when working with the same strain of resistant insects or mites, major differences can arise in the expression and thus detection of resistance, depending upon the test methods employed (Dennehey et al 1983, McCaffery unpublished).

With this in mind, PEG-US chose to try to resolve differences of opinion within the industry by evaluating four commonly used bioassay techniques; topical application (Anon 1970), larval dip test (Watkinson et al 1984), foliar residue test (Collins et al 1988) and an adult vial test (Plapp, 1988) for the detection of pyrethroid resistance in Heliothis virescens. As a result of this work, the benefits and limitations of each method have been documented, and a scheme of use developed which takes account of the different criteria which must be satisfied in various phases of resistance monitoring. Each technique was shown to be valid and to have a potential role, and the relationship between test results was determined to allow some degree of comparison between the different methods (Riley et al 1988).

On a much broader front, IRAC has chosen to review resistance detection methods for all key pests across a range of crop sectors. The objectives of this study are similar to those of PEG-US; namely to achieve a harmonisation of methodology to allow debate to focus on the interpretation of monitoring data, not its validity. Apart from the cotton workgroup, who have made use of the findings of PEG-US, the most advanced group is that concerned with top fruit, the findings of which are published in this conference (Lemon 1988).

The process of education

In order to propagate the message of judicious insecticide management, education must proceed on many levels, and through various media. A valuable development in this area has been the production of an IRAC/FRAC video on resistance and its management. The video aims to address some basic facts about resistance: what it is, how it develops, how it can be managed and the role of industry in achieving management. The video provides the basic groundwork upon which local education programmes can be developed. However, it is important to bear in mind that the video cannot fulfil the education role unaided; this can only be achieved through a carefully developed programme which takes into account specific situations and the needs and incentives which must be satisfied before the target audience will respond positively to the management message.

Another key role that the multinational industry can play is to disseminate information across national boundaries. Members of PEG and

IRAC are frequently invited to speak at national and international crop protection conferences, which provide an excellent forum for such "technology transfer". Even more valuable, is the sponsorship of exchange visits between influential members of the cotton growing communities of different countries. An excellent example of this was the industry-sponsored exchange between Australia and Colombia in 1988. Most recently, PEG has sponsored the visit of a Colombian entomologist to the USA, where she will receive training aimed at helping her to develop and manage a government resistance monitoring programme on her return.

Finally, another important aspect of education which is generally overlooked is the role that PEG and IRAC representatives have in negotiating support from their commercial colleagues.

Basic research

Not unexpectedly, the major thrust behind basic research comes from individual agrochemical companies as they seek for the "magic bullet" of a replacement toxicant in a competitive environment. This is an entirely healthy attitude, and one which I hope will prove successful, for the sake of the cotton-growing community. Nevertheless, there are technical areas in which the industry has seen fit to co-operate. In the case of pyrethroid resistance in *Heliothis virescens*, PEG has sponsored a three-year, multidisciplinary project, aimed at elucidating the mechanisms and heritability of resistance, at Reading University in England.

Less than one year into the study, the group has already demonstrated what it believes to be the major mechanisms of resistance. Electrophysiological studies have demonstrated at least two categories of nerve insensitivity in resistant strains, and biochemical studies have shown greatly increased metabolism and excretion of cypermethrin as a conjugate of 4-OH' cypermethrin, indicative of oxidative metabolism (Little *et al*. 1988). A future aim of the group is to develop rapid diagnostic assays for each resistance mechanism detected, to enable management decisions to be taken in field at the time of each insecticide spray.

INDUSTRY CONTRIBUTION TO INSECTICIDE RESISTANCE MANAGEMENT

As we have seen, in pursuing their prescribed remits, IRAC and PEG have contributed to almost every area highlighted as important to the success of resistance management in the field. Working Groups have been developed to encourage links and co-operation within and outwith the industry; facts have been drawn together and disseminated to indicate the spread and severity of resistance problems; new data have been generated through the instigation of collaborative monitoring programmes, facilitating the definition of management tactics; detection methodology has been rigorously evaluated to ensure commonality of opinion with respect to the facts of resistance; programmes of education have been supported through the production of media messages and through cultural exchanges; basic research into the mechanisms and heritability of resistance has been funded (Table 1).

It is always difficult to review attempts at resistance management in the field and to attribute the outcome to specific factors. Nevertheless, I am confident that the efforts of the agrochemical industry have significantly aided progress, particularly in Australia and the USA, where the pyrethroids continue to dominate *Heliothis* control measures within the adopted management strategies. Provided that future efforts aim to satisfy the requirements for success laid down by Sawicki and Denholm (1987), where they are controllable, industry can and should continue to make valuable contributions to insecticide resistance management.

TABLE 1

Industry contributions to insecticide resistance management

i Management infrastructure	- Development of industry-wide workgroups (PEG, PEG-US, IRAC, etc) - Links forged with non-industry research organisations
ii Establishing the facts	- IRAC global survey of resistance - Resistance definition - Research priorities highlighted - Resistance monitoring programmes (Thailand, Turkey, USA)
iii Basic research	- Developing detection methods - Research into resistance mechanisms - Competitive work to find replacement toxicants
iv Education	- IRAC/FRAC resistance video - Cultural exchange visits - Training of local entomologists - Gaining support from commercial/ marketing colleagues

THE WAY FORWARD

Not only does the agrochemical industry take the threat of resistance very seriously: it responds accordingly. A statement to which I trust the examples quoted in this paper adequately attest. Nevertheless, there are a number of areas, highlighted in the introduction as important factors, which are either not being addressed or need further development. This is not to say that such areas are the sole responsibility of the agrochemical industry. Indeed, it seems likely that much of this work needs to be led from outside, but supported through, the industry.

A major gap in our knowledge is our understanding of the biology and population dynamics of Heliothis spp worldwide. This information is a basic building block of all resistance management strategies, and good guesswork may prove inadequate in the long term. Additionally, validation of chosen strategies needs to be addressed, using monitoring techniques which adequately reflect pyrethroid field performance.

Although good progress has been made with inter-company co-operation amongst manufacturers with similar products (ie the pyrethroids), there will be increasing pressure to achieve total insecticide management in cotton and indeed other crops (Morton & Collins 1988). IRAC and the US agrochemical manufacturers are beginning to address this issue, but more needs to be done to resolve the problems of potential conflicts of interest through such co-operation.

Finally, with respect to education, there is a clear need for the development of industry-sponsored programmes at the farmer level aimed at encouraging judicious insecticide usage. The industry is often better equipped than other members of the cotton community to achieve this. The responsibility is a general one, not just restricted to resistance management, and is an ongoing aim of all the agrochemical manufacturers both individually and collectively through GIFAP.

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RESISTANCE MONITORING METHODS AND STRATEGIES FOR RESISTANCE MANAGEMENT IN INSECT AND MITE PESTS OF FRUIT CROPS

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ABSTRACT

On the basis of a worldwide survey, the Fruit Crops Working Group of the Insecticide Resistance Action Committee (IRAC) has identified the major resistance problems in pests of fruit crops.

Recommended resistance monitoring methods have been developed for *Panonychus ulmi* and *Tetranychus* spp. (eggs and adults), *Psylla* spp. and *Myzus persicae*.

The merits of various resistance management strategies are discussed and a provisional approach to resistance management in spider mites on deciduous fruit crops is proposed.

INTRODUCTION

The establishment of the Insecticide Resistance Action Committee (IRAC) under the umbrella of the International Group of National Associations of Agrochemical Manufacturers (GIFAP) was described by Voss (1987). IRAC's task is to provide expert advice to GIFAP on all technical and scientific matters relating to insecticide and acaricide resistance, to coordinate industry's efforts to prolong the life of pesticides by defining appropriate technical strategies and to develop research relationships with non-industrial institutions.

IRAC has established a number of working groups based on crops or problems and this paper describes the progress made by the Fruit Crops Working Group since it was set up in 1985.

IRAC Fruit Crops Working Group - members, 1988:

R. W. Lemon	Schering Agrochemicals Limited (Chairman)
C. Erdelen	Bayer AG
A. St. J. Green	Merck Sharp & Dohme Research Laboratories
A.C. Grosscurt	Duphar B.V.
P.K. Leonard	Dow Chemical Company Limited
H.P. Streibert	Ciba-Geigy AG
J. Tipton	Shell International Chemical Company Limited
A. Waltersdorfer	Hoechst AG

In order to set priorities for future work, in 1985, IRAC initiated an extensive survey of resistance problems through its own member associations and companies. The results of this survey were analysed by the Working Group and published by Voss (1988). The analysis was based on IRAC's definition of field resistance. For the term "resistant" to be applied, the following criteria must be met:

- The product for which resistance is being claimed carries a use recommendation against the particular pest mentioned, and has a history of successful performance.
- Product failure is not a consequence of incorrect storage, dilution or application, and is not due to unusual climatic or environmental conditions.
- The recommended dosages fail to suppress the pest population below the level of economic threshold.
- Failure in control is due to a heritable change in susceptibility of the pest population to the product.

The perceived problems were divided into three categories.

In the first category were grouped those cases where resistance rendered chemical control difficult or uneconomic in a number of countries. These were cases where involvement by industry had become essential:

Pest	Crop	Resistance to Chemical class	Territories
Myzus persicae	peaches	OP's	Worldwide
		carbamates	France, Italy Portugal, Australia
Psylla spp.	pears	OP's, pyrethroids	Europe, N.America
Aonidiella aurantii	citrus	OP's	Greece, mid-East S.Africa
Panonychus ulmi & Tetranychus spp.	top fruit	various	Worldwide
Panonychus citri	citrus	various	U.S.A, Japan, Italy

In the second category were those cases which have the potential of becoming more serious. Careful observation and initiation of monitoring programmes was recommended.

Pest	Crop	Resistance to Chemical class	Territories
Eriosoma lanigerum	apples	OP's	Spain
Phorodon humuli	hops	OP's, carbamates	Europe
Cydia pomonella	pome fruit	OP's	Argentina
Leucoptera scitella	pome fruit	OP's, benzoylureas	Italy
Lithocolletis blancardella	pome fruit	OP's, pyrethroids	Greece, Italy U.S.A.
Sparganothis pilleriana	grapes	OP's	Spain
Brevipalpus phoenicis	citrus	various	Brazil
Eotetranychus carpini	grapes	various	France
Distantiella theobroma Sahlbergella singularis	cocoa	chlorinated hydrocarbons	Ghana

In the third category were cases considered to be of low priority at this time, which will remain in IRAC's database but will not lead to action in the foreseeable future.

The problems identified in category 1 were ranked by the Fruit Crops Working Group into the following order of priority for development of monitoring methods and recommendations for resistance management.

1. Panonychus ulmi/Tetranychus spp. - deciduous fruit
2. Psylla spp. - pears
3. Myzus persicae - peaches
4. Panonychus citri - citrus
5. Aonidiella aurantii - citrus

MONITORING METHODS

An effective susceptibility monitoring programme to obtain baseline data and to detect early signs of resistance in field populations of insects and mites is an important component of any resistance management strategy.

Many companies undertake resistance monitoring programmes using their own test methods but standardisation of these methods is seen as an important step in a cooperative approach to resistance management, particularly where different companies as well as non-industrial institutes are working with the same class of compound.

During the past three years, members of the IRAC Fruit Crops Working Group, in consultation with non-industry experts have developed and validated simple but reliable proposed methods for the following species:

Panonychus ulmi and Tetranychus spp. - eggs and adults
Psylla spp. - nymphs
Myzus persicae - adults

The methods are designed to be used by field personnel without sophisticated laboratory facilities and to simulate the field treatment conditions as closely as possible.

Descriptions of the methods are now available from GIFAP. It is emphasised that the methods have been validated for specific compounds or classes of compounds only and modifications may be required for compounds with different modes of action.

The following is a brief summary of each of the methods currently available.

Spider mite adults

Slide-dip methods as recommended by FAO (Anon 1974) have frequently been used for spider mite resistance tests. The disadvantages of this type of test compared with residual bioassays were demonstrated by Dennehy, et al (1983).

The method adopted by IRAC is a whole leaf residual contact assay based on that described by Welty, et al (1987) in work on cyhexatin resistance in P.ulmi.

Apple or plum leaves are dipped for five seconds in selected dilutions of the test formulation and then placed top surface uppermost on a layer of moist cotton wool in a 9cm. open petri dish. A strip of damp cotton wool 1cm. in width is laid around the perimeter of the treated leaf, half over the leaf and half over the cotton wool bed.

Ten adult female mites are then placed on the surface of the treated leaf. After a recommended exposure period, the mortality is assessed using a binocular microscope or hand lens.

The method has been validated for bromopropylate, cyhexatin, dicofol, formetanate and propargite.

Summer eggs of P.ulmi and eggs of Tetranychus spp.

The method adopted is similar to that recommended by FAO and described in Anonymous (1974). Sections of plum or apple leaf are placed top surface uppermost on a sheet of moist filter paper on moist cotton wool in open petri dishes. Ten-fifteen adult female mites collected from the field are placed on each leaf section and maintained at a minimum temperature of 20°C., minimum photoperiod 16 hours and a high light intensity, but not in direct sunlight.

After a maximum of 48 hours, when sufficient eggs have been laid, the mites are removed. The leaf sections with eggs are then dipped in the test liquids for five seconds. The leaf sections are returned to the petri dishes and maintained in the conditions described above until hatch can be recorded.

The method has been validated for clofentezine, hexythiazox and tetradifon.

Winter eggs of P.ulmi

Short pieces of twig bearing eggs are taken from the field. The twigs are split into two longitudinally and sections bearing a minimum of 25 eggs are dipped into the test liquids for five seconds. When dry, the twig sections are placed on a film of petroleum jelly in a petri dish and egg numbers are counted. The dishes with lids replaced are stored outside but protected from rain and direct sunlight. When egg hatch is complete, numbers of hatched larvae are recorded.

The method has been validated for clofentezine and hexythiazox.

Pear psylla

Shoots infested with immature stages are collected from the field. The best time is when 1st and 2nd instar nymphs of the second generation are present. It is important to treat before much honeydew is produced.

The shoots are placed in water and the number of live nymphs recorded. The shoots are dipped for ten seconds in the test liquid and then kept at room temperature for 24 hours before assessing numbers of surviving nymphs.

The method has been validated for organophosphates and amitraz.

Myzus persicae

Uninfested peach tree leaves are dipped into the test liquids for ten seconds, allowed to dry and then placed lower surface uppermost individually in petri dishes. A small piece of damp cotton wool is placed around the petiole of each leaf. Each leaf is infested with 20 adult aphids collected from the field. Mortality is assessed after 24 hours by checking the aphids ability to show coordinated movement in response to a touch with a small brush.

The method has been validated for organophosphates and carbamates.

In addition to the conventional monitoring methods described above, biochemical methods are being considered where they can be conveniently used under the conditions described above.

STRATEGIES FOR RESISTANCE MANAGEMENT

The ultimate objective of all IRAC Working Groups is to agree and recommend strategies aimed at preventing or delaying the onset of resistance in the field and the management of resistance where it already exists.

Ideally, such strategies should be based on an understanding of the resistance mechanisms involved and the inheritance of these mechanisms. However, such studies take time and when a product is first introduced, the company can only assess the risk of resistance and has to decide whether to recommend the compound in a way that will reduce that risk to a minimum.

Similarly, when resistance first occurs in the field, the manufacturer does not have time for detailed investigations before taking action in an attempt to manage the situation.

The first priority of the Fruit Crops Working Group of IRAC was to develop a recommended strategy for spider mite control in deciduous fruit, where there is a long history of resistance problems.

It was agreed that the strategy adopted should be based on consideration of all methods available for control of the pest and the use of these methods in the best possible way to minimise the risk of resistance.

Chemical methods include the use of a variety of products, e.g. organotins, propargite, amitraz, dicofol, bromopropylate, flubenzimine, pyrethroids, tetradifon, clofentezine and hexythiazox and biological methods, the use of predatory mites (including OP-resistant Typhlodromus) and insects.

The published literature together with strategies implemented by the Fungicides Resistance Action Committee and by the Pyrethroid Efficacy Group were reviewed and the Fruit Crops Working Group concluded that the options available for spider mite resistance management were as follows:

1. Use of mixtures of acaricides subject to different resistance mechanisms.

2. Alternation/rotation of acaricides

3. Moderation of use:

   - Reduced rates (in conjunction with biological control)
   - Less frequent application (linked with more use of threshold numbers and improved scouting)
   - Localised treatments

Mixtures applied as coformulations, are from the company's point of view, easier to control than alternations/rotations. However, in addition to being subject to different resistance mechanisms, ideally the components of a mixture should have equal residual activity which can seldom be achieved (Curtis 1985). They should act on the same stage in the life cycle and in order to gain the full benefit they should be used at full rates which is seldom economic.

Furthermore, the build-up of resistance to one component of the mixture may be masked by the activity of the other component until it reaches a high level and is then more difficult to manage.

Rotation was therefore selected as the basis of the recommended strategy, but clearly compounds used in rotation like those in mixtures should not be subject to the same resistance mechanisms.

The acaricides available were therefore grouped according to known or expected cross-resistance patterns, although it was accepted that knowledge of cross-resistance patterns was incomplete and considerable research would be required to clarify the situation. The provisional list is as follows. As knowledge improves this will be revised.

Group A Organotins (Edge & James, 1983) (Balevski, 1983)
Group B Clofentezine, hexythiazox (Gough, 1987*)
Group C Bridged diphenyl compounds
Group D Pyrethroids
Group E Flubenzimine
Group F Tetradifon
Group G Amitraz
Group H Propargite
Group I Quinomethionate
Group J Benzoximate
Group K Dinobuton

* Case referred to was on roses.

The following guidelines in the use of acaricides are based on the above groups:

1. Not more than one compound from any one group should be applied to the same crop in the same season.

2. Any one compound should be used only once per season on any one crop.**

3. Compounds from the same group must not be mixed.

4. Compounds should be used in such a way that detrimental effects on predatory insects and mites are minimised.

5. Use compounds only at manufacturer's recommended rates and timings.

6. Monitoring should be conducted to detect early signs of resistance.

** Because of specific activity against certain life stages, some compounds may be recommended for two successive applications to provide effective control.

Agreement on a proposed strategy is only the beginning. Implementation of that strategy will not be easy. It will require not only cooperation between the agrochemical companies but cooperation with advisers/extension personnel and most importantly, the growers themselves. The ways in which this will be achieved will be the subject of discussion at future meetings of the Working Group.

PROPOSALS FOR FURTHER WORK

Work to establish cross-resistance patterns in spider mites will be funded by IRAC. A decision on where to place this project has not yet been made.

A high priority will be given to the implementation of the resistance management strategy for spider mite control in top fruit.

Monitoring methods will be developed for Panonychus citri and Leucoptera scitella but in view of a reduction in the use of broad-spectrum OP's on citrus, work on a method for Aonidiella aurantii has been postponed.

Resistance management strategies will be developed for pear psylla and for Myzus persicae control on peaches based on the same principles as those used in the recommendations for spider mite control.

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PRACTICAL APPROACHES TO MANAGING ANTI-RESISTANCE STRATEGIES WITH DMI FUNGICIDES

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ABSTRACT

DMI fungicides are widely used for the control of a broad spectrum of important cereal pathogens. Changes in DMI sensitivity in UK cereal mildew populations have prompted the introduction of anti-resistance strategies for these compounds. Evidence is presented to support the use of alternation and mixture of DMI's with fungicides of different modes-of-action, to provide cost effective treatments for the cereal grower whilst counteracting the development of fungicide resistance.

INTRODUCTION

Fungicides which inhibit the C-14 demethylation step of sterol biosynthesis (DMI fungicides) are now used widely on cereals, vines, top fruit, bananas, vegetables, ornamentals and many other crops. Under the auspices of GIFAP (Groupement Internationale des Associations Nationales de Fabricants de Pesticides), industry formed the Fungicide Resistance Action Committee (FRAC) to deal with pathogen resistance to the different classes of fungicides. Working groups were initiated and one such is concerned with the DMI fungicides. This paper, written on behalf of this working group, seeks to address the subject of fungicide strategies for temperate cereals which together represent the major market sector with the greatest crop value for these fungicides.

CEREAL PATHOGENS

The cereal farmer in Western Europe has a diversity of disease problems to contend with. On barley, powdery mildew (*Erysiphe graminis* f.sp. *hordei*) is undoubtedly the greatest threat to yield, though important consideration must also be given to net blotch (*Pyrenophora teres*), leaf scald (*Rhynchosporium secalis*), eyespot (*Pseudocercosperella herpotrichoides*), brown and yellow rust (*Puccinia hordei* and *Puccinia striiformis*) and to the seed and soilborne pathogens including *Ustilago nuda*, *Ustilago hordei*, *Pyrenophora graminea* and *Fusarium* spp. On wheat, mildew (*Erysiphe graminis* f.sp. *tritici*) dominates yield considerations, closely followed by leaf spot and glume blotch (*Septoria tritici* and *Septoria nodorum*). As in barley, rusts, eyespot and seedborne diseases may also be important, dependent upon the prevailing environmental conditions and the susceptibility of the cultivar grown.

CHEMICAL CONTROL MEASURES

To combat this diverse collection of pathogens, spanning three taxonomic subdivisions of the fungi, the West European farmer currently has at his disposal five classes of systemic fungicide, each with a different mode of action. Additionally he may employ a number of older non-mobile protectant molecules.

Four types of systemic molecule were launched in the late 1960's to early 1970's; the hydroxypyrimidines (ethirimol, dimethirimol, bupirimate), the morpholines (tridemorph and fenpropimorph) the benzimidazoles (benomyl, thiophanate-methyl, carbendazim, thiabendazole [TBZ]) and the carboxamides (carboxin), Ethirimol represented a major technical advance when it was introduced in 1969 as a seed treatment for the control of powdery mildew on barley. The narrow spectrum of activity of ethirimol was the major limitation of the product. The morpholine fungicides utilised only as foliar sprays provided the grower with an excellent eradicant treatment for mildew and rusts but only moderate additional spectrum of activity and a relatively short persistence of action. The benzimidazoles though useful initially for eyespot and Fusarium control have poor activity against the cereal powdery mildews. Similarly, the activity of carboxin on cereals is restricted to control of smuts and bunts.

It was against this background that the first of the triazole based DMI fungicides triadimefon, triadimenol and propiconazole, were launched in the late 1970's. They had high levels of activity against mildews and rust, were more persistent than morpholines, and also had a broad spectrum of action against other pathogens. Furthermore triadimenol could also be applied as a seed treatment to control foliar, seed and soilborne diseases.

The arrival of the triazole DMI fungicides greatly simplified control of the growers' disease problems and it is not surprising that their sales increased in value from £30M in Western Europe in 1978 to £210M in 1983 (Godwin *et al.* 1988), as DMI's became the dominant feature of cereal fungicide treatment.

DEVELOPMENT OF ANTI-RESISTANCE STRATEGIES

The widespread use of ethirimol in the UK in the early 1970's was followed by a decline in sensitivity in the barley powdery mildew population (Shephard *et al.* 1975). In response to this, the use of the chemical was restricted. Other cases of changing sensitivity to systemic fungicides had already been reported, including resistance to benzimidazoles on cucurbits in Holland (Schroeder & Provvidenti 1969), and it was apparent that systemic fungicides with their specific mode of action, had a greater proclivity for resistance development than older multi-site compounds. Changes in sensitivity to DMI fungicides were reported in UK barley mildew populations by Fletcher and Wolfe (1981). Although field efficacy was little affected at this point, this report provided added impetus in the search for more robust application strategies than the frequently recommended sequential DMI programmes.

Several mathematical models constructed to predict the events that lead to the development of resistant subpopulations generally agreed that alternation or mixture of fungicides with different modes of action would increase the time necessary for resistance outbreaks to occur (Skylakakis 1982). Growth chamber studies by Staub and Sozzi (1983) with Phytophthora infestans further supported the concept of mixtures (metalaxyl and mancozeb) as an anti-resistance strategy. Other supportive evidence, however, was scarce and the models themselves had many inherent weaknesses. Few considerations were made for fitness differences between resistant and sensitive phenotypes and no consideration was given to the possibility that resistance might be controlled multigenically. Hollomon (1981) had identified just such a complex control of ethirimol resistance in barley mildew.

From this incomplete picture of potential resistance management techniques, industry began to search for practical demonstrations that mixtures or alternations could act, not only as anti-resistance strategies, but could also provide cost-effective treatments for the farmer. His concerns are first and foremost with performance and yield and not resistance.

Mixtures/Alternation; performance considerations

In 1984 a mixture of a DMI fungicide, flutriafol and a hydroxypyrimidine, ethirimol, was launched as a seed treatment for the control of foliar and seedborne disease of barley (Northwood *et al.* 1984). This treatment was superior to a straight triadimenol treatment for barley mildew control (Table 1). Its efficacy is based upon a dual mode of action against mildew, the ethirimol component proving effective as a result of the re-sensitisation of the mildew population to ethirimol in the early 1980's (Heaney *et al.* 1984). This was probably due to the decline in ethirimol usage during this period as DMI treatments became established.

TABLE 1

% Mildew control, spring barley, 1984

Location	Cambs.		Suffolk		Glos.	
Wks after drilling	8	13	8	13	8	13
Untreated (Actual)	(3.4)a	(10.4)a	(7.7)a	(16.7)a	(15.7)a	(46.8)a
FF4050*	99c	99c	90c	93c	99c	97c
Triad/fub'zole	80b	78b	72b	58b	90b	69b
Ethirimol (+Hg)	98c	97c	88c	85c	99c	97c
Leaf Assessed	L4	L4	L2	L3	L3	L2

Source : Northwood *et al.* 1984

* Flutriafol + ethirimol + thiabendazole

Mixtures have also demonstrated their utility where control of more than one cereal pathogen is an important component of yield. Mixtures of propiconazole with a morpholine partner were superior to either component used alone against mildew and net blotch on spring barley in Scotland (Miller *et al.* 1984), Table 2. On wheat, mildew and S.tritici commonly occur together and in such situations the value of mixtures can again be demonstrated (Table 3). Both cases highlight an important point for the farmer who cannot afford the luxury of compartmentalising individual diseases into individual stategies of application.

TABLE 2

The influence of different fungicide application strategies on barley mildew and net blotch control in Scotland, 1984

Treatment	Rate (g a.i./ha)	% Mildew* 21-24DAT1	% Net blotch* 18-39DAT2**	Yield as % untr.
Propiconazole	125	2.6	1.7	123
Propiconazole + tridemorph	125+250	0.5	0.8	129
Propiconazole + fenpropimorph	125+300	0.2	1.2	125
Fenpropimorph	750	0.3	17.8	118
Untreated	-	18.1	15.8	(5.9)

Source : Miller *et al.* (1984)

* Mean of six sites in Angus
** 18 to 39 days after the 2nd application
( ) tonnes/ha

TABLE 3

The influence of different fungicide application strategies on wheat mildew and Septoria tritici control in England, 1985

Treatment	Rate (g a.i./ha)	% Mildew* 22DAT3	% S.tritici* 22DAT3	Yield as % of untr.
Propiconazole	125	7.5	0.8	118
Propiconazole + tridemorph	125+250	0.8	1.0	140
Triadimenol	125	1.5	12.5	124
Untreated	-	30.0	25.0	(4.8)

Source : Ciba-Geigy data

* Disease assessment on the flag leaf
( ) tonnes/ha

On spring barley, when mildew was the principle disease, alternation and mixture programmes all provided better disease control and yield than sequential DMI treatments (Table 4). Where triadimenol sensitivity was particularly low at the East Anglia site, mixture programmes resulted in higher yield increases (15-20%) than a DMI/morpholine alternation strategy (9%). Similar yield increases have been reported for a spring barley programme utilising a flutriafol/ethirimol seed treatment followed by a piperidine (morpholine cross-resistance group) spray. Yield increases were 13% greater than those of a sequential DMI programme (ICI data).

Influence of mixtures/alternation on sensitivity

A common criticism of fungicide mixtures is that they may select for resistance to both components of the mixture. Since this would affect the efficacy of any mixture programme it is important to evaluate in the field, the relative selective forces exerted by a proposed mixture.

TABLE 4

Comparison of the efficacy of different fungicide application programmes for control of barley mildew at Long Ashton (LA) and in East Anglia (EA), 1987

Prog.	Seed treatment*	Foliar spray**		% Mildew control LA 17DATA****	EA 14DATA	Rel. yield*** LA	EA
1	Untreated	Untreated		(5.4)*****	(23.2)	(5054)	(2892)
2	Triadimenol	Triadimenol	(A+B)	89	0	109	103
3	Triadimenol	Triadimenol + tridemorph	(A+B)	88	75	116	120
4	Triadimenol	Tridemorph	(A+B)	84	77	112	115
5	Triadimenol	Tridemorph Triadimenol	(A) (B)	97	75	119	109
6	Triadimenol + ethirimol	Triadimenol + tridemorph	(A+B)	99	71	115	115

Source : Bayer data

* Triadimenol rate = 375 ppm a.i., ethirimol 2000 ppm a.i.
** First application (A) at GS30-31, second application (B) at GS53-57
Triadimenol (125 g a.i./ha), tridemorph (375 g a.i./ha)
*** ( ) kg/ha, 85-86% dry matter
**** 17 days after foliar application (A)
***** % leaf area infected

In trials on spring barley in England in 1987, sequential treatments of triadimenol were shown to select for isolates less sensitive to triadimenol (Table 5). Programmes employing mixtures of triadimenol with ethirimol or tridemorph counteracted this selection towards triadimenol resistance, with mixtures being slightly more effective than alternations at the Long Ashton site (Table 5). Sequential triadimenol treatments selected for significantly increased sensitivity to ethirimol at Long Ashton where isolates demonstrated a negative cross-resistance between triadimenol and ethirimol. Triadimenol/ ethirimol mixtures did not select for either triadimenol or ethirimol resistance. Similar findings were observed in 1985 (Table 6) and by Hunter *et al*. (1984). In both studies ethirimol when used alone did select for lower levels of ethirimol sensitivity.

Mixtures and alternation programmes using propiconazole and tridemorph also counteracted selection for propiconazole resistance in barley mildew (Bolton & Smith 1988), (Table 7). Mixtures were more effective in this respect and demonstrated better disease control and yield response.

TABLE 5

Comparison of the effect of different fungicide application programmes on the fungicide sensitivity of barley powdery mildew populations in England, 1987

Programme*	Triadimenol sensitivity (ED50 ppm)**		Ethirimol sensitivity (ED50 ppm)***	
	Long Ashton	East Anglia	Long Ashton	East Anglia
1. Untreated	0.8a****	3.3a	1.8a	1.0a
2. Sequential DMI	4.9c	5.0a	1.3b	1.2a[b]
3. DMI/morpholine mix.	1.2ab	-	-	-
4. DMI/morpholine alt.	1.6b	2.9a	-	-
5. DMI/morpholine alt.	2.0b	2.9a	-	-
6. DMI/ethirimol : DMI/morpholine seq.	0.9a	3.4a	1.9a	1.6 [b]

Source : Bayer data

* Programme numbers refer to those given in Table 4
** Samples taken after the second spray
*** Samples taken immediately before the first foliar application at GS30-31
****Values with different letters have non-overlapping 95% confidence limits

TABLE 6

Effect of fungicide treatments on sensitivity in barley powdery mildew in England, 1985

Treatment	Fungicide sensitivity (ED50 ppm)	
	Triadimenol	Ethirimol
Untreated	1.9	0.6
Triadimenol	2.2	0.5
Ethirimol	1.4	1.9
Triadimenol + ethirimol	1.4	0.5

Source : Bayer data

Longer term sensitivity trends

Various systemic mixture treatments have been in widespread use in the UK since 1984, and it remains important to monitor population sensitivity in order that their overall influence may be judged. The launch of a mixture of ethirimol with flutriafol as a seed treatment brought about a dramatic increase in ethirimol input, though not to the detriment of ethirimol sensitivity levels (Table 8). The mean ethirimol sensitivity of the population has changed little from 1984 to 1988, though there are signs of a slight selective response in the form of an increase in intermediate types (Grades 12-17) at the expense of highly sensitive phenotypes (Grade >17) (Table 8).

TABLE 7

The influence of different fungicide application strategies on barley mildew control, grain yield and sensitivity to DMI fungicides in England, 1987

Application strategy	Foliar spray*	% Leaf area infected 15DAT1**	14DAT2	DMI sensitivity LC90 (ppm a.i.) propiconazole 25DAT2	Yield as % of untreated
Continuous DMI	Propiconazole	6.6	26.8	19.6	126
Mixture	Propiconazole + tridemorph	1.2	4.7	12.6	144
Alternation	Propiconazole/ tridemorph	0.5	11.9	15.4	139
-	Untreated	37.7	85.0	13.4	(5.4)
LSD P = 0.05		7.3	7.9	6.2	10.5

Source : Bolton & Smith (1988)

* First spray applied at GS30-31, second application at GS53-57. All seed was treated with triadimenol (375 ppm) + fuberidazole (45 ppm) + imazalil (50 ppm)

** 15 days after the 1st foliar application

( ) tonnes/ha

TABLE 8

Changes in sensitivity to ethirimol in barley mildew populations in England, 1973-1988

Year	Distribution of sensitivity scores* <6	6-9	9-12	12-15	15-17	>17	Mean sensitivity
1973	5	14	41	21	12	7	11.6
1974	1	16	60	13	7	2	10.8
1977	0	0	19	76	4	1	13.1
1984	1	4	10	26	27	32	15.1
1985	0	4	4	48	20	24	14.7
1986	0	0	3	54	36	7	14.8
1987	0	1	20	56	21	2	13.5
1988	0	0	9	68	20	3	13.9

Source : ICI data

* Values are percentages of samples (from treated and untreated fields) in each category. The sensitivity scale is from 0 (least sensitive) to 20 (most sensitive) and is described in detail by Shephard *et al.* (1975)

DMI sensitivity declined sharply in England from 1984 to 1985 (Heaney *et al.* 1986) but has not changed significantly since and there were signs in 1988 that the frequency of the most resistant phenotypes had declined (Table 9). It is tempting to speculate that the move away from sequential DMI treatments towards mixtures and alternation programmes has contributed to arresting this decline. However, it is important to recognise that all isolates tested by ICI in 1988 demonstrated a significant level of resistance to DMI's.

TABLE 9

Changes in sensitivity to triadimenol in barley mildew populations in England, 1985-1988

Year	Distribution of sensitivity scores*					Mean
	<5	5-9	9-13	13-17	>17	sensitivity
1985	22	31	28	14	5	9.3
1986	19	40	37	4	0	8.6
1987	31	38	26	5	1	7.0
1988	9	49	40	1	0	8.1

Source : ICI data

* Values are percentages of samples (from treated and untreated fields) in each category. The sensitivity scale is from 0 (least sensitive) to 20 (most sensitive) and is described in detail by Heaney *et al.* (1986)

Wolfe *et al.* (1988) reported isolates of barley mildew with reduced sensitivity to fenpropimorph (in Scotland) and tridemorph (in England). These isolates were screened out at very low discriminating doses (1/100 and 1/20 field rate respectively) and were not detected on untreated plants, indicating their low frequency in the population. Heaney *et al.* (1986) failed to detect such phenotypes in the UK and these findings were repeated in 1988. If changes in morpholine sensitivity are taking place, the process is clearly at a very early stage and it would be wise to continue careful monitoring studies.

CONCLUSIONS

Mixtures and alternation programmes can clearly make an important contribution to counteracting the progress of fungicide resistance in cereal mildew populations in the UK. Mixture treatments, in particular, can provide valuable returns for the grower. Programmes similar to those described above have been increasing in popularity since 1984 in the UK and are now widely recommended by the agrochemical industry.

Preformulated mixtures provide the grower with safe and simple, cost effective programmes where active ingredients are utilised in optimal ratios. Tank mixture recommendations for individual components provide additional flexibility to the grower. Both approaches have an advantage over alternation programmes, in that they provide spectrum of disease control and ease of correct implementation.

Future strategies in cereals will increasingly have to consider other cereal pathogens. Changes in DMI sensitivity in S.tritici and R.secalis populations might reasonably be predicted in the medium term and there is clearly a need to monitor morpholine sensitivity closely in the case of powdery mildew.

Early detection of such changes will aid in the application of approaches similar to those used currently, and there may need to be more careful consideration in the use of other weapons in the armoury, for example, protectant molecules and varietal resistance. It would be dangerous to be complacent in other areas, and whilst prochloraz sensitivity remains high in eyespot populations in Europe (Birchmore *et al.* 1986) prochloraz applications should be judiciously administered to minimise the selection pressure on eyespot and other cereal pathogens.

Important differences may emerge between the DMI fungicides themselves. We have assumed in this paper that DMI fungicides will all fall into the same cross-resistance group. Whilst on barley mildew this appears to be the case for the triazoles mentioned here; triadimenol, triadimefon, propiconazole and flutriafol (Hollomon, pers. comm.), new molecules may be discovered which break this conventional grouping. Berg *et al.* (1987) have proposed that the triazole terbuconazole (HWG1608), inhibits Δ^7 dehydrogenation in addition to C-14 demethylation. Isomers of this molecule demonstrated significantly different levels of activity against triadimenol resistant strains of Pyricularia oryzae. Whether these differences translate into useful field characteristics remains to be seen.

The problems of DMI resistance management will become more complex and it is only through the exchange of ideas and information between industry, the grower and advisors that successful strategies will evolve for the future. The Fungicide Resistance Action Committee (FRAC) and its working groups should provide a valuable mechanism to aid this difficult process.

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STRATEGIES TO CONTROL DICARBOXIMIDE RESISTANT STRAINS OF *BOTRYTIS CINEREA*

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ABSTRACT

In long term trials on grapes attempts were made to develop a strategy to maintain effective *Botrytis* control by dicarboximides despite the widespread occurence of Dicarboximide resistant strains. This aim could be achieved by limiting the number of applications to two or at the most three per season or growing cycle and thus reducing the selection pressure. As is proved by the results presented, this strategy works well due to the special characteristics of dicarboximide resistant strains, whose percentage in a given population varies depending on the selection pressure throughout the year. Since prolonged periods without selection pressure result in a remarkable decrease of the resistant population, their percentage can be maintained at a relatively low level, even though one to three applications are sufficient to cause resistant strains to reach maximum levels (90-100 %) in the pathogen population again. As the application of combinations does not reduce the selection pressure the same rules have to be observed as for the use of dicarboximides alone. On the other hand, the application of combinations is highly recommended in situations were resistance is well established, since they stabilize the performance of the dicarboximides. This resistance management strategy can also be applied to other crops as well as to grapes.

INTRODUCTION

Between 1975 and 1977, the dicarboximides iprodione, vinclozolin and procymidone were registered in France, Federal Republic of Germany, Italy and Switzerland for the control of grey mould, *Botrytis cinerea*, in grapes (Beetz and Löcher, 1979). According to general recommendations, the dicarboximides may be applied at rates from 750 - 1000 g a.i./ha.

The first dicarboximide-resistant field strains of *B. cinerea* were found in a vineyard in the Mosel growing area in the autumn of 1978 (Holz, 1979). In 1979, resistant isolates were found in all other vine-growing areas of West Germany (Spengler *et al*, 1979; Lorenz and Eichhorn, 1980). In 1980, they also appeared in vines in Switzerland (Schüepp *et al*, 1982) and in France (Leroux *et al*, 1982). Due to the lack of good alternative fungicides, dicarboximide use was continued for *Botrytis* control in the vine-growing areas of the countries mentioned above. As a consequence the proportion of resistant strains in the pathogen population increased considerably in these regions. Botrytis strains resistant to dicarboximides were also found in vineyards in Italy, New Zealand and Canada (Beever and Brien, 1983; Gullino et al., 1982; Northover and Matteoni, 1984). Further reports relating to the appearance of dicarboximide-resistant Botrytis isolates are mainly concerned with strawberries, vegetables and a wide variety of glasshouse crops. Nowadays they occur worldwide, wherever dicarboximides have been used intensively for a number of seasons.

Initial studies and research projects on dicarboximide resistance management were started in Germany as early as 1979 (Löcher et al., 1985). The aims of these projects were to determine possible strategies to prevent the spread of dicarboximide resistance and to maintain effective Botrytis control.

According to Delp (1980), there are three possible ways to prevent or delay the development of resistance to fungicides by:

1. decreasing the number of treatments in order to reduce the selection pressure,

2. combining active ingredients,

3. alternating spraying sequences, when effective substances with different modes of action are available.

Attempts were made to establish whether these measures would also be effective when resistance is already present. Since benzimidazole resistance is as widespread as dicarboximide resistance and due to the fact that, at the present time, no other equally effective Botryticides are available, efforts have been concentrated on the first two points mentioned above. A number of compounds effective against B. cinerea were tested in combination with dicarboximides and the number of treatments varied. The results of these studies have already been published and discussed in detail (Löcher et al., 1987). Since then additional data have been created. The most effective combinations in grapes proved to be those with either chlorothalonil or thiram. Trials, especially with the latter combination, will be continued. The strategies derived and their possible relation to other crops is discussed in the light of the data concerning 1) performance and Botrytis control and 2) the influence of either vinclozolin alone or in combination on the population dynamics of resistant strains.

MATERIALS AND METHODS

The materials and methods used are similar to those already described by Löcher et al., (1987).

The dicarboximide fungicide used was a wettable powder containing 50 % vinclozolin. Fungicides tested in combination with vinclozolin were chlorothalonil and thiram at rates of 1.0 kg and 3.2 kg/ha respectively. Chlorothalonil had to be used at a reduced dose since the product causes unacceptable russeting of berries at higher rates.

The spraying dates were determined according to the Eichhorn and Lorenz-scale, which describes the development stages (see Löcher et al., 1987). Metiram was used for downy mildew control in all trials.

Each experimental plot contained 25 vines and covered an area of about 50 m^2. The number of replicates was 2-6. To evaluate Botrytis attack, 6 times 100 bunches of grapes per treatment were classified in 6 categories. From the data obtained, the % disease intensity was calculated (Löcher et al., 1987).

To determine the sensitivity of Botrytis strains to vinclozolin, diseased plant material was sampled several times per year from 5-8 sites in each plot. Wood samples were taken in February, inflorescences and leaves were collected in June/July, and grapes and leaves were collected in October shortly before harvest. The procedures and methods used for the preparation of samples, and the isolation and testing of the Botrytis strains are the same as those described by Löcher et al., 1987.

RESULTS

In the interpretation of the results, the varying degrees of Botrytis infection and the differences in main infection periods must be borne in mind (Table 1).

Table 2 contains all the data available concerning Botrytis control with either vinclozolin alone or the respective combinations in relation to disease intensity in untreated plots for the years 1980 up to 1987. Even though the Filzen-vineyard in the Mosel growing area represents the most complete history of trial results with vinclozolin combinations over the years, data are not always complete. In 1982, no vinclozolin treatment was included, and in 1986, the vinclozolin/thiram combination was omitted. This was due to limitations in space at a time when more important trial questions had to be investigated. Nevertheless, the most important facts and tendencies are shown very clearly.

Considering the performance of vinclozolin alone, there is a clear correlation between disease intensity and control of Botrytis. In years with only light Botrytis infection, efficacy of vinclozolin is still good; there are no differences in control values between resistant vinclozolin and the combinations with either chlorothalonil or thiram. In all years with severe Botrytis attack (over 25 % infestation) the performance of vinclozolin tended to become unstable. This tendency was more pronounced when five rather than three applications were made (see 1981, 1984, 1987). In 1986, with an extremely heavy infection pressure, vinclozolin was no longer able to control Botrytis, although in 1987, when the disease intensity was still high (28 %), its performance was again fairly good.

As has already been mentioned, the combination of vinclozolin and chlorothalonil achieved the best results of those tested during the initial trial period (Löcher et al., 1987). In comparison thiram at a rate of 1.6 kg a.i./ha in combination with vinclozolin performed less well (Löcher et al., 1987). With an increase in the thiram rate from 1.6 to 3.2 kg a.i./ha, it was possible to obtain results as good as those with the chlorothalonil mixture. This is shown very clearly by the results obtained in 1984 and has also been well documented by further trial results (Löcher, in press). In view of these data and due to the fact that chlorothalonil causes phytotoxicity problems in grapes, trials with the chlorothalonil mixture were abandoned, whereas the vinclozolin /thiram mixture was pursued further (Table 2).

A comparison of the control values obtained with vinclozolin alone with those of the two combinations over the years, allows the conclusion that the performance of the combinations in general is slightly to significantly better and results are more stable than with vinclozolin alone; the only exception being in those years when Botrytis attack is light. This seems to be independent of the number of treatments and the disease intensity.

Data concerning the population dynamics of resistant strains are presented in Table 3. Since the effects of vinclozolin and its combinations on the proportion and population dynamics of dicarboximide-resistant strains have already been discussed in detail (Löcher et al., 1987), only three major points will be considered again here:

1. Influence of disease intensity and infection periods
2. Influence of the number of treatments
3. Influence of the treatment itself

As can be seen from the data in Table 3, the proportion of resistant strains varies greatly according to the time of year. Besides type and number of treatments, weather conditions and infection pressure are probably the most important factors. In years with a high infection pressure, an increase in the proportion of resistant strains can be observed in the untreated plots until October. This increase runs parallel to that in the treated plots but at a significantly lower level. This is most often the case when five applications have been made, with the initial application early in the season. However, in years with a low infection pressure and/or unfavourable infection conditions, the opposite may be observed, i.e. a steady decrease in the proportion of strains up to October, not only in the untreated control plots but also in treated plots. This was observed in 1982 when the initial number of resistant strains was high. Alternatively, a uniformly low level of these strains may be recorded throughout the season, as in 1985. In treated plots, slight variations in the rate of increase following the treatments in different years can also be explained by the infection conditions prevalent in these years. In 1980, for example, there was a heavy early Botrytis infection (Table 1) and the major increase in the proportion of resistant strains occurred up to July after two applications of vinclozolin. In contrast, in 1981, when there was a heavy but late infection pressure, the greatest increase in the resistant population occurred between July and October.

The selection pressure exerted by the number of applications made each season is also clearly visible and remarkable. From 1980 to 1982, when 4 or 5 treatments were made, the percentage of resistant strains increased constantly from one year to the other. This is especially pronounced at the sampling date in February and is only slightly counteracted by the decrease caused by unfavourable infection conditions during 1982. Only in 1984, after only two applications in 1983, could a general drop in the percentage of resistant strains in all plots, especially at the sampling dates of February and July, be observed. During the following 3 years, in which 3 applications were made late in the season, the resistant population established itself at a fairly low and uniform level in the untreated plots. Due to the prolonged period without selection pressure, seasonal variations became more pronounced, with the lowest levels of resistant strains normally observed during July.

With respect to the selection pressure extended by treatment, data are very clear cut and consistent throughout the years. There is no difference between either an application of vinclozolin alone or the use of combinations. Independent of the number of treatments, the combination used and the initial precentage of resistant strains vinclozolin alone as well as the respective combinations caused the same increase in the resistant population. Three and even two applications were sufficient for the resistant strains to obtain maximum levels (90-100 %).

Similar results as those presented here for grapes were also obtained in other crops. Trials in strawberries (especially in everbearing strawberries, where a high number of applications are necessary) confirmed the two facts: 1) that a combination with thiram, for example, was very efficient with respect to Botrytis control, but 2) it caused a similar increase in the percentage of resistant strains in the population, as did vinclozolin alone (Löcher, in press).

These results were further confirmed by data obtained on several greenhouse crops (Löcher, in press).

DISCUSSION

Due to the special characteristics of dicarboximide-resistant Botrytis strains (i.e. lower fitness and pathogenicity) their proportion within a population varies greatly depending on the selection pressure throughout the year (see references in Pommer and Lorenz, 1982 and 1987). Although they do not disappear completely from a population their numbers may drop to a certain minimum level during periods without selection pressure. However the proportion of resistant strains in the population increases again rapidly when a new selection pressure is exerted. Depending on infection pressure, the initial amount of resistant strains and, to a certain degree, the crop, one to three applications are sufficient to cause the resistant population to return to maximum levels. As shown by the results presented here, successive prolonged periods of selection pressure cause a gradual increase in the total numbers of resistant strains present. As this occurs seasonal variations tend to become less pronounced. Additionally, the results prove that the use of combinations, a measure which is effective with other groups of fungicide (e.g. De-methylation inhibiting fungicides), is not effective with the dicarboximides in reducing the selection pressure. This is mainly due to the fact that those fungicides presently available as combination partners to dicarboximides are themselves only comparably weak Botryticides. However, they do help to stabilize Botrytis control considerably in situations where resistance is well established.

Thus with dicarboximides, the only possible way to reduce the selection pressure is to minimize the number of applications. At the same time it is important to ensure regular, prolonged periods without selection pressure. Strategies based on these principles have proved to be valid over the last few years, although general recommendations vary slightly depending on the crop concerned (Löcher in press). The results presented here for grapes, as well as those for other crops, prove that it is possible to maintain effective Botrytis control using dicarboximides in spite of the occurrence of resistant strains by the use of soundly based resistance management strategies.

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TABLE 1

Botrytis attack on grapes (1980 - 1987) at the Mosel growing area

Year	Main infection periods at vine development stage*											% Disease intensity
	15	17	19	23	25	29	31	33	34	35	38	in untreated areas
1980		+	+					+	+	+	+	27
1981								+	+	+	+	30
1982							+			+	+	13
1983			+								+	7
1984									+	+	+	39
1985		+										8
1986										+	+	62
1987			+						+	+	+	27

* Eichhorn/Lorenz scale

TABLE 2

The effect of vinclozolin alone and in combination with chlorothalonil or thiram on Botrytis control in Müller-Thurgau grapes, Filzen/Mosel region during the years 1980-1987

Year	Number of treatments at development stage**	% Disease intensity (Duncan's test) Untreated		Vinclozolin		Vinclozolin + Chlorothalonil		Vinclozlin + Thiram	
1980	17, 19, 25, 32, 34	27	(C)	16	(AB)	11	(A)	-	
1981	17, 25, 32, 34, 35	30	(B)	29	(B)	12	(A)	-	
1982	25, 32, 34, 35	13	(C)	-		4	(A)	-	
1983	32, 34	7	(B)	2	(A)	3	(A)	-	
1984	32, 34, 35	39	(C)	20	(B)	14	(A)	13	(A)
1985	32, 34, 35	8	(C)	3	(A)	-		3	(A)
1986	32, 34, 35	62	(C)	58	(C)	-		-	
1987	*(25), 32, 34	28	(E)	17	(CD)	-		15	(C)

* Application at development stage 25 only with the combination Vinclozolin + Thiram
** Eichhorn/Lorenz scale

TABLE 3

The effect of vinclozolin alone and in combination with chlorothalonil or thiram on population dynamics of dicarboximide-resistant strains of Botrytis cinerea in Müller-Thurgau grapes, Filzen/Mosel region during the years 1980-1987

Year	Number of treatments at development stage**	Treatment	% resistant strains February	July	October
	↓	Untreated	0	43	42
1980	17, 19, 25, 32, 34	Vinclozolin	30	88	92
		Vinclozolin + Chlorothalonil	30	88	92
	↓	Untreated	27	50	70
1981	17, 25, 32, 34, 35	Vinclozolin	52	71	100
		Vinclozolin + Chlorothalonil	35	66	100
	↓	Untreated	66	10	0
1982	25, 32, 34, 35	Vinclozolin	-	-	-
		Vinclozolin + Chlorothalonil	100	85	50
	↓	Untreated	40	50	20
1983	32, 34	Vinclozolin	60	*	95
		Vinclozolin + Chlorothalonil	50	*	90
	↓	Untreated	0	20	20
1984	32, 34, 35	Vinclozolin	20	0	80
		Vinclozolin + Chlorothalonil	20	40	70
		Vinclozolin + Thiram	0	50	90
	↓	Untreated	11	20	11
1985	32, 34, 35	Vinclozolin	20	14	20
		Vinclozolin + Thiram	20	20	30
	*	Untreated	20	*	43
1986	32, 34, 35	Vinclozolin	10	*	93
		Vinclozolin + Thiram	-	-	-
	↓	Untreated	35	27	20
1987	32, 34	Vinclozolin	50	13	80
	25, 32, 34	Vinclozolin + Thiram	33	47	93

↓ June/July sampling; * no samples taken due to lack of Botrytis cinerea; ** Eichhorn/Lorenz scale