IRAC SURVEY OF RESISTANCE OF STORED GRAIN PESTS:

RESULTS AND PROGRESS

John S. BADMIN

Shell Research Ltd, Sittingbourne Research Centre
Sittingbourne
Kent ME9 8AG
England

Abstract

The Insecticides Resistance Action Committee (IRAC) is a consultative group to GIFAP **(Groupement International des Associations Nationales des Fabricants de Produits Agrochemiques)** on technical and scientific subjects relating to insecticide resistance. IRAC has the task of co-ordinating industry's efforts of prolonging the life of insect control agents, and to foster working relationships with non-industrial scientists concerned with solving resistance problems.

The IRAC Sub-Committee on stored grain pests circulated a questionnaire to operating companies world-wide requesting information on the extent of resistance of stored grain pests in commercial stores. Replies were received from Australia, Philippines, Indonesia, Malaysia, Taïwan, India, South Africa, Kenya, Zimbabwe, Côte d'Ivoire, France, UK, USA and Brazil. Resistance was ranked according to level and area affected on a 1-3 scale.

130 reports of field resistance were reported during the survey period (1985-86), representing a total of 16 species of insect and mite. Four species of beetle and one moth were identified as Category I priority cases for industrial engagement. Several Category II pests, adequately controlled at present but with potential to acquire a wider spectrum of resistance were also identified.

More recently IRAC has concentrated on developing practical methods for monitoring field resistance of Category I pests, with a view to exchanging data within the industry. Funds supplied by IRAC to the Natural Resources Institute, UK, have assisted in the development of a transportable kit for monitoring resistance in stored grain pests.

Introduction

The setting of the Insecticide Resistance Action Committee (IRAC) under the auspices of GIFAP (Groupement International des Associations Nationales des Fabricants de Produits Agrochemiques) has been described by Voss (1987). IRAC's main role is to provide expert advice to GIFAP on all subjects relating to insecticide and acaricide resistance, to co-ordinate industry's efforts to prolong the life of pesticides by defining appropriate technical strategies, and to foster research relationships with non-industrial organisations.

IRAC has established a number of working groups concerned with crops and more recently with specialist topics (eg Bt management) and published a regular Newsletter on resistance in the GIFAP Bulletin. This paper describes the survey work carried out by the Stored Products Sub-Committee.

Materials and Methods

The Survey

In 1985, the Sub-Committee circulated a questionnaire to operating companies world-wide requesting information on the extent of resistance of stored grain pests in commercial stores in each country. It was intended that the survey should provide up-to-date information on resistance of a more commercial nature than the last comprehensive global survey carried out by FAO (Champ & Dyte, 1976).

For the term 'resistant' to be applied, the following criteria were necessary.

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

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

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

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

Replies to the questionnaire were received from Australia, Philippines, Indonesia, Malaysia, Taïwan, India, South Africa, Kenya, Zimbabwe, Côte d'Ivoire, France, United Kingdom, USA, and Brazil. Approximately one hundred and thirty reports of field resistance were noted during the period of the survey (1985-1986), representing a total of sixteen species of insect and mite (Table I).

The quality and reliability of the data varied according to the sources of information available to the local operating company. Information on stored grain pests, unlike information on crop pests, was often supplied by a third party specialist operator rather than the operating company itself, due to the relatively small size of the stored products market. Other sources included internal reports, government surveys and results published in the open literature. A large amount of reliable data was supplied by Slough Laboratories and NRI (UK), CSIRO (Australia) and USDA (USA).

Multiple reports were received from those regions of the world, notably Melanesia and Australia, where field resistance was considered most acute and where a monitoring infrastructure existed already. Some differences in ranking the resistance problem were identified, but in general operating companies often substantiated each other's independent observations.

The committee felt that although the most important species and the main pockets of field resistance had been identified, more data from South America, West Africa, the Indian sub-continent and Communist Block countries were required to complete a world-wide picture.

Results

Three categories of resistance were recognised. Species in the Category I termed 'Priority R-cases for industrial engagement' were those where the resistance levels were considered sufficiently high that their control by chemical means was either difficult or uneconomic.

TABLE I. STORED PESTS SHOWING INSECTICIDE RESISTANCE

Coleoptera:	Tribolium castaneum (Herbst)
	T. confusum Duval
	Sitophilus granarius (L.)
	S. oryzae (L.)
	S. zeamais Motschulsky
	Oryzaephilus surinamensis L.
	Rhyzopertha dominica (F.)
	Alphitobius diaperinus Panz.
	Cryptolestes ferrugineus Stephens (and related species)
	Dermestes maculatus Deg.
	Callosobruchus chinensis L.
	Trogoderma granarium Everts
Lepidoptera:	Sitotroga cerealella (Olivier)
	Plodia interpunctella (Hubn)
	Ephestia cautella (Walker)
	E. kuehniella Zell.
Acarina:	Acarus siro L. (and related species)

Four species of beetle and one moth were identified as priority cases and their status is discussed below. Information received on their patterns of resistance is summarised in Table II.

Coleoptera

Flour beetle Tribolium castaneum

This species is perhaps the most common stored products pest, with a distribution extending from tropical to cool temperate regions of the world.

Resistance to malathion and lindane by this species has become more widespread as predicted in the FAO survey. However, specific products or mixtures are still available for control of this insect, and resistance is of immediate concern primarily in France, Indonesia and the Philippines. Resistance to phosphine in Australia and the United Kingdom, whilst of concern, has not increased in intensity as predicted and phosphine fumigation remains an effective means of control in most countries.

Grain weevil Sitophilus granarius

This beetle is a temperate species, controlled mainly by fumigants. Whilst FAO have reported resistance to pyrethrins and phosphine in S. granarius under field conditions, it is generally controlled at present by available compounds. However, a major problem exists in France where a replacement for lindane seed dressing is needed.

Rice weevil Sitophilus oryzae

This species is the most important storage pest of raw cereal and any occurrence of resistance to grain protectants is of considerable economic importance. High levels of resistance to OCs, OPs and carbamates, coupled with a well-developed pattern of cross-resistance, were reported from the Philippines during the current survey. FAO have also reported instances of field resistance to phosphine and 'pyrethrins'. Although existing control measures may be satisfactory in most cases, it is likely that this species will remain a cause of concern.

Saw-toothed grain beetle Oryzaephilus surinamensis

The status of this species as a pest has increased steadily since the FAO report in 1976. Strains collected from many locations in the United Kingdom where control failure may have occurred have been shown to be multi-resistant. In some strains, cross-resistance extends to organochlorines (DDT), synthetic pyrethroids and the fumigant methyl bromide. This species is a cause for concern in the United Kingdom and Australia on a short/mid term basis.

Lepidoptera

Angoumois grain moth Sitotroga cerealella

This moth is a serious grain pest in many parts of the world. The infestation by this moth starts in the field and may reach serious levels before being transferred to grain stores. Widespread resistance to malathion and localised resistance to phosphine of an unspecified nature have been reported from Brazil during the current survey. Further investigation of the situation is required before the nature of the problem can be assessed.

TABLE II. PROBLEM SPECIES IN STORED PRODUCTS

Product/Pest		Countries												
		A	P	I	M	T	In	SA	K	Z	Fr	UK	USA	B
Organochlorines														
Tribolium	r		1		3		3				-			
castaneum	a	+	2		2		2				2			
Sitophilus	r										-			
granarius	a										2			
S. oryzae	r	3	3								-			
	a	1	2								2			
Organophosphates														
Tribolium	r	3		3	3		3	2	2			3	2	1
castaneum	a	3		3	2		2	3	2			1	1	2
Sitophilus	r	3						2						
granarius	a	3						3						
S. oryzae	r	3	3					2						
	a	3	1					3						
Oryzaephilus	r	3										2		
surinamensis	a	3										3		
Sitotroga	r													2
cerealella	a													3
Carbamates														
S. oryzae	r	3												
	a	2												

Countries

Left to Right: Australia, Philippines, Indonesia, Malaysia, Taïwan, India, South Africa, Kenya, Zimbabwe, France, UK, USA, Brazil.

Degree of Resistance: (r) Resistance factor 1=<10x, 2=10-30x, 3=>30x.

Area of Resistance: (a) Indicates the size of area affected 1 = small, local problem only, 2 = considerable area affected, 3 = entire crop area affected.

(+) Resistance recorded, extent unknown.

(-) No value provided.

In Category II were grouped those species which have the potential of developing into problem pests. Careful monitoring of these species is required. Species in this category were:

Flour mite Acarus species complex

Several species of mite occur commonly in grain and the principal species are considered to be Acarus siro and Glycyphagus destructor (Schrank). At present A. siro is a cause for concern in the United Kingdom, not in grain stores but in cheese stores where it has acquired total resistance to treatment with lindane. Tests indicate that resistance extends to some OPs.

The concern is two-fold. First, that individuals of strains of A. siro prevalent in cheese stores will gain entry into grain stores leading to the need to treat infected grain on a more regular basis. Secondly, that A. siro is not one but a complex of species which includes A. chaetoxysilos (Oudemans) and A. farris Griffiths in addition to A. siro. Interbreeding occurs in the wild, and hybrid mites with intermediate morphological characters have hampered correct identification of the mite(s) involved. The major worry is that if resistant genes are transferable from A. siro to other members of the complex then resistance may become more widespread in the future.

Confused flour beetle T. confusum and flat grain beetle Cryptolestes sp.

The survey highlighted two additional species in which the incidence of phosphine resistance was a cause for concern. Low levels of resistance to phosphine were reported for Tribolium confusum in the United Kingdom, and Cryptolestes sp. originating from the Far East. In many situations the use of fumigants is the only, or the most effective form of treatment, and so any resistance to these products is viewed with anxiety. Loss of control with fumigants may lead to the need to develop completely new methods of storage/treatment.

In the third category were species considered to be of low priority (eg Callosobruchus chinensis), requiring no input from IRAC at the present time.

Discussion

i) Recommendations

The stored grain pests whose control is hampered most by problems of resistance are Tribolium castaneum, Sitophilus granarius, S. oryzae, Oryzaephilus surinamensis and Sitotroga cerealella. Despite the patterns of resistance that have emerged, it is considered that products or mixtures of products already on the market, and new products about to be introduced will provide effective control of these species for the time being. Industry is at present actively developing pyrethroids for this outlet, and a number of juvenile hormone analogues and acylureas await evaluation. Each of these chemical groups acts by an entirely different mode of action and unless cross-resistance occurs, should not lead to further pressure on existing genotypes.

For example, synthetic pyrethroid space sprays have been developed for control of adult Plodia and Ephestia moths in recent years, as a successful alternative to treatment of grain with OPs for control of the larval stages of these insects.

Strategies for delaying the selection of resistance to new compounds (ie new resistant genotypes) that will require more attention by industry include the use of mixtures of compounds from two or more novel chemical groups and/or the use of compounds on a rotational basis. Both will require greater industry co-operation.

The Acarus mite complex and the strains of Tribolium confusum and Cryptolestes species resistant to phosphine are considered longer-term problems. It is expected that the current range of products together with newer introductions will control these pests for the foreseeable future. For example, the local problem of resistant cheese mites in the United Kingdom can be controlled by a number of OP products and the fumigant methyl bromide.

Resistance to phosphine and other fumigants not only by the beetles listed above poses a very serious problem in the longer term. Few safe fumigants are available for use per se. Such products are acutely toxic to humans, and require supervised handling procedures. Fumigants are considered to be very effective, cheap, broad spectrum compounds and in many situation where residues are unacceptable (eg in stored flour) the only candidates available for use.

Loss of these products may require the industry to develop radically different methods of storing foodstuffs, such as controlled atmospheres, or even developing new fumigant(s) with attendant problems of toxicology and most probably lack of patent coverage. If the latter approach is adopted and is indeed feasible, it will require a great deal of industrial and government co-operation to select the preferred candidate(s).

(ii) The Future

One of the most important factors governing the management of pesticide use is the availability of sound baseline data on the susceptibility of target pests to insecticides. IRAC has therefore concentrated more recently on developing practical methods for monitoring the field resistance of Category I pests, with a view to exchanging data within industry and between interested third parties. Details of the proposed insecticide/acaricide susceptibility tests recommended by IRAC have been published in OEPP/EPPO Bulletin (Anon, 1990).

After reviewing the available methods for monitoring resistance in stored product pests, including new biochemical techniques, IRAC decided to opt for the 'original' FAO type method, since this is well documented and can be directly related to the performance of products in the field. Discussions have been held with Natural Resources Institute, UK with a view to developing a modified FAO test using insecticide pre-treated filter papers (Taylor, 1989). Discriminating doses have been established for organophosphates, and tests are in progress to determine equivalent doses for pyrethroids. IRAC has encouraged these studies and provided equipment for prototype test kits. Useful advice has also been received from MAFF, UK, with regard to discriminating doses for other species.

The next stage is to evaluate the prototype test kit more comprehensively, under a variety of field conditions in order to establish its reliability. Eventually it is hoped that grain store managers, or those directly involved in the daily practicalities of controlling infestations of stored products will make use of the kits.

References

Anon (1990) Proposed insecticide/acaricide susceptibility tests developed by Insecticide Resistance Action Committee (IRAC) Bulletin OEPP, 20, 389-404.

Champ B.R. and Dyte C.E. (1976). Report of the FAO global survey of pesticide susceptibility of stored grain pests, Rome: FAO.

Voss G. (1987) Insecticide/acaricide resistance: Industry's efforts and plans to cope. International Congress of Plant Protection, 1987, Abstract, 88.

Taylor R.W.D. (1989) A simplified approach to resistance testing for beetle pests of stored products in the field. BCPC Monograph No 43, Progress and Prospects in Insect Control, UK.

ETUDES DE L'"IRAC" SUR LA RESISTANCE DES RAVAGEURS DES GRAINS STOCKES : RESULTATS ET PROGRES

John S. BADMIN

Shell Research Ltd. Sittingbourne Research Center
Sittingbourne Kent ME9 8AG
England

RESUME

Le Comité d'Action sur la Résistance aux Insecticides (IRAC) est un groupe de consultants spécialisés dans l'étude des données techniques et scientifiques relatives à la résistance aux insecticides et fait partie du GIPAF (Groupement International de Produits Agrochimiques). L'IRAC a la tâche de coordonner les efforts de l'Industrie pour prolonger la durée d'utilisation des produits insecticides et d'encourager les relations de travail avec les scientifiques chargés de la résolution des problèmes posés par la résistance.

Le sous-comité de l'IRAC sur les ravageurs des grains stockés a distribué dans le monde entier aux sociétés concernées, un questionnaire demandant des précisions sur l'étendue des phénomènes de résistance des ravageurs des stocks de grains dans les unités de stockage. Les réponses sont parvenues d'Australie, des Philippines, d'Indonésie, de Malaisie, de Taïwan, d'Inde, d'Afrique du sud, du Kénya, du Zimbabwe, de la Côte d'Ivoire, de France, du Royaume Uni, des USA et du Brésil. Une échelle de 1 à 3 a été attribuée à la résistance selon son niveau et la zone affectée.

130 rapports sur la résistance au champ ont été remis lors de la période de surveillance (1985-1986). Ils mentionnaient au total 16 espèces d'insectes et d'acariens. Quatre espèces de coléoptères et une espèce de lépidoptère ont été classées dans la catégorie I des cas de priorité pour l'industrie. On a également identifié plusieurs ravageurs de catégorie II, normalement éliminés actuellement mais risquant d'acquérir un plus large éventail de résistance.

Plus récemment, l'IRAC s'est concentré sur le développement de méthodes pratiques de contrôle de la résistance sur le terrain des ravageurs de la catégorie I, en vue de favoriser les échanges d'informations entre les différentes firmes concernées. L'IRAC a fourni des fonds à l'Institut des Ressources Naturelles pour le Développement Outre-mer, (GB). Ces fonds ont aidé à développer un kit transportable servant à mesurer la résistance des ravageurs des grains stockés aux insecticides.