SESSION 6A

INNOVATIVE METHODS OF PEST AND DISEASE MANAGEMENT

Chairman	Dr H F Evans *Forest Research Agency, Farnham, UK*
Session Organisers	Dr H F Evans *Forest Research Agency, Farnham, UK* and Dr C Prior *Royal Horticultural Society, Wisley, UK*
Papers	6A-1 to 6A-4

Virus-mediated biological control of fungal plant pathogens

C M Brasier
Forest Research Agency, Alice Holt Lodge, Farnham, Surrey, GU10 4LH, UK

ABSTRACT

In some fungal plant pathogens, deleterious RNA viruses exert a degree of natural biological control. In the chestnut blight and Dutch elm disease pathosystems for example, virus frequency is being studied in relation to changes in pathogen population structure and different viruses are being compared for their biocontrol properties under field conditions. In addition, the molecular properties of the viruses are being investigated with a view to understanding their mode of action, modifying their phenotypic effects and improving their efficiency of spread. Recently, virus transformed isolates of the chestnut blight fungus have been experimentally released into the field. The way may eventually be open to designing RNA viruses tailor-made to control particular fungal pathogens or pathogen populations.

INTRODUCTION

Intracellularly transmitted RNA-based viruses and virus-like agents are common in fungi (Buck, 1986, 1998; Nuss & Koltin, 1990; Ghabrial, 1994). Owing to their mode of transmission, which is passive from hypha to hypha and does not involve infection, they are likely to be highly host specific (Milgroom, 1998). Most fungal viruses appear to be relatively benign. However, some have a marked debilitating effect on the growth and development of their fungal hosts. Among these are the virus that causes 'La France' disease of the cultivated mushroom (Fletcher, White & Gaze, 1989) and several viruses that affect plant pathogens including those of the chestnut blight and Dutch elm disease pathogens (see below) and those of the take-all fungus of wheat (*Gaeumannomyces tritici*) (Duffey & Weller, 1996), *Rhizoctonia* damping-off fungus (Ichielevich-Auster *et al.*, 1985) and the virus of *Sclerotinia* dollar spot fungus of turfgrasses (Zhou & Boland, 1998). In each of these plant pathogens, interest has recently focused on the use of their viruses as an alternative to fungicides in disease control.

Among the fungal pathogen-virus systems that are fairly well characterised, are the chestnut blight (*Cryphonectria parasitica*) and Dutch elm disease (*Ophiostoma novo-ulmi*) systems. These will now be used to exemplify what is being learned of the natural spread of viruses in pathogen populations, mechanisms of pathogen restriction of virus spread, virus variability, the mode of delivery of viruses as biological control agents and the potential for further genetic manipulation of viruses.

VIRUSES OF THE DUTCH ELM DISEASE AND CHESTNUT BLIGHT PATHOGENS

Chestnut blight is a canker disease and the trees are killed by the girdling action of the fungus, while Dutch elm disease is a vascular wilt disease that enters the sapstream of the tree via feeding wounds in twig crotches made by the vector (carrier) elm bark beetles. Both Dutch elm disease and chestnut blight had been introduced into new, susceptible host populations in Europe and North America this century, resulting in the destruction of most mature native elms and chestnuts across these regions respectively. As these pathogens have spread, deleterious viruses have also actively spread in their populations, causing degenerate growth, reduced conidial (asexual) spore production and viability and reduced production of sexual structures (perithecia) in these fungi. Significantly, it is well documented that natural remission of chestnut blight, due to the spread of fungal viruses, occurred in Europe during the 1950s (Heiniger & Rigling, 1994). In Dutch elm disease, circumstantial evidence suggests that the unexpected decline of the first epidemic of the disease (caused by *O. ulmi*) in Europe during the 1940s also involved the spread of viruses in the pathogen population (Mitchell & Brasier, 1994).

Vegetative compatibility and virus spread

The viruses of *C. parasitica* and *O. novo-ulmi* are relatively freely transmitted via the asexual conidia of both species but are rarely transmitted into the sexual spores (ascospores). However, accumulated evidence suggests that the rate of natural spread of viruses is most strongly influenced by the frequency of different 'vegetative incompatibility' (vc) genotypes in *C. parasitica* and *O. novo-ulmi* populations. Fungal vc systems are analogous to animal tissue incompatibility systems. They are controlled by multiple genes with multiple alleles. Potentially, therefore, many unique vc genotypes can exist. If adjacent fungal colonies are of a different vc type, they are 'incompatible': viruses cannot readily pass from one individual to the other via hyphal fusions because the fusion cells die. When two colonies carry the same vc genes, however, they are 'compatible' and viruses can spread readily between them because any hyphal fusions are functional (e.g. Anagnostakis & Day, 1979; Brasier, 1986; Liu and Milgroom, 1996). In the chestnut blight pathogen, *C. parasitica*, there is a negative correlation between the success of natural disease remission or 'hypovirulence', caused by *C. parasitica* hypoviruses and the number of vc types present in a population (vc type diversity) (Anagnostakis *et al.*, 1986). Populations in Europe exhibit only a few vc types (have low vc type diversity) and, in these, significant natural disease remission has occurred. Populations in eastern North America have high vc type diversity, and here no disease remission has been observed, despite repeated virus introductions (reviewed in MacDonald & Fulbright, 1991; Heiniger & Rigling, 1994 and Milgroom, 1998).

The Dutch elm disease pathogen, *O. novo-ulmi*, usually spreads at epidemic fronts as a single vc type clone. In Europe, viruses spread extensively in these frontal clones such that 50-90% of isolates may become virus infected. However, the fungus quickly diversifies (*c.* 5 years) into numerous new vc types. This is followed by a marked decline in virus frequency. The selection pressure exerted by the viruses is believed to select for the appearance of the new vc types (Brasier, 1988), while the new vc genes themselves may be acquired in *O. novo-ulmi* through transfer of vc genes from *O. ulmi* (Brasier *et al.*, 1998).

Deployment of wild-type viruses of the chestnut blight and Dutch elm disease pathogens for biocontrol

As has been indicated above, the best opportunity for successful release of wild-type, as opposed to genetically modified, viruses as biocontrol agents is in a location where the pathogen populations has low vc diversity. With Dutch elm disease, suitable large stable vc clones have been shown to exist in Oregon and Washington DC in western and eastern North America (Brasier, 1996) and also in New Zealand. Field experiments have shown that the viruses of *O. novo-ulmi*, by severely reducing conidial viability, can prevent the fungus infecting elm trees via beetle feeding wounds (Webber, 1987, 1993). The beetle feeding wound is therefore the most effective point at which viruses have potential for controlling Dutch elm disease, although viruses are lost from isolates that successfully infect the vascular system.

In contrast, the saprotrophic phase of the Dutch elm disease fungus is essentially a continuous bark-to-bark cycle from which the vascular wilt phase in elm xylem is only a side loop (Webber & Brasier, 1984). Viruses are spread mainly in this saprotrophic phase (Brasier, 1986). Theoretically, an appropriate experimental strategy would be to release bark beetles carrying virus infected fungal spores of the same vc type as the locally dominant vc clone. The released beetles should home in on the nearby wild beetle populations breeding in diseased elm bark. In this way, the virus should be spread into the saprotrophic population of the fungus associated with the beetle breeding galleries. The presence of virus should be sustained in this bark-to-bark cycle, while at the same time the rate of infection of healthy elms via beetle feeding wounds, and therefore epidemic development, should be reduced.

So far, the properties of 13 different viruses of *O. novo-ulmi* from Europe have been characterised *in vitro*. The same 13 viruses have also been tested in the field for their effectiveness in preventing infection of elm via beetle feeding wounds and shown to range through the entire spectrum from mild to severe in their effects (Sutherland & Brasier, 1995, 1997). Several North American *O. novo-ulmi* viruses are also undergoing similar tests. On the grounds that moderate viruses might be expected to survive better as biocontrol agents than very severe viruses (Webber, 1993), it has been proposed that moderate viruses only or mixtures of mild, moderate and severe viruses should be deployed for biocontrol (Sutherland & Brasier, 1997). The fact that viruses of *O. novo-ulmi* often exhibit latency (delayed expression) should further enhance their survival and therefore their biocontrol potential (Rogers, Buck & Brasier, 1986).

In the chestnut blight fungus, isolates carrying a deleterious virus, known as 'hypovirulent' isolates, do not cause spreading aggressive cankers on chestnut trees. Moreover, if a virus is transferred from a hypovirulent isolate on a tree to an adjacent virulent isolate via hyphal fusions, conversion of the virulent isolate to hypovirulence occurs (Van Alfen *et al.*, 1975). This process is the basis of both natural disease remission and artificial disease control by viruses in the chestnut blight system. For artificial control, in situations where virulent cankers are developing on chestnut trees, hypovirulent isolates of the same vc type as the local virulent isolates can be inoculated into the bark around the margins of the cankers, converting the virulent cankers to hypovirulence. The relatively low diversity of vc types among *C. parasitica* populations in Europe has enabled successful artificial deployment of wild-type hypoviruses for disease control in chestnut orchards in France, Italy and Switzerland since the late 1960s (e.g. Heiniger & Rigling, 1994).

Deployment of genetically modified viruses for biocontrol

Where vc diversity in the target pathogen population is high, as with chestnut blight in eastern North America or Dutch elm disease in Europe, the barrier to virus transmission may be overcome by release of genetically modified viruses or fungal isolates. The molecular biology of the viruses of both pathogens is therefore being investigated.

A number of different types of virus are known to exist in both *C. parasitica* and *O. novo-ulmi*, (Buck,1998). The most widely studied virus of the chestnut blight pathogen, known as CHV1 is a single unencapsidated *c.*12 kb dsRNA (reviewed in Nuss, 1993, 1996). CHV1 is closely associated with membrane bound vesicles in the cytoplasm of the fungal cell. It apparently induces hypovirulence by downregulation of certain pathogenically related functions. These include several major enzyme systems (laccase, cellulase, protease and polygalacturonase). Also downregulated is a GTP binding protein or G-protein, which has a main regulatory function in signal transduction. This G-protein, in particular, appears to have a major role in the expression of the hypovirulence phenotype.

Recently, the genome of the CHV1 virus has been inserted into a plasmid vector in the laboratory. Using this vector, cells of a wild-type (virus-free) *C. parasitica* isolate have been successfully transformed with a full length cDNA transcript of the virus, resulting in a nuclear copy of the virus that is inherited in the fungus as a single gene (Choi & Nuss, 1992). Not only is this remarkable, but (i) the inserted 'gene' gives rise to cytoplasmic viruses that function as normal *C. parasitica* hypoviruses; (ii) using normal sexual crosses between the virus transformed isolate and wild-type *C. parasitica* isolates, the gene can be recombined into ascospores and hence into other vc types, half the progeny inheriting the new 'gene' in a Mendelian fashion. This experiment has therefore demonstrated the potential to spread the virus readily into other vc types, something that is critical to successful virus release where the pathogen population is of high vc diversity. In 1996, the US Environmental Protection Agency gave permission for two trial releases of CHV1 transformed *C. parasitica* into the field to assess its survival ability and disease control potential. So far, there is some evidence for its preliminary spread from the original vc type into new vc types (Anagnostakis *et al.*, 1998).

The virus most studied in *O. novo-ulmi* so far, the d^2-factor, is associated with 3 out of 10 small (<3 kbp) unencapsidated RNAs which reside in the mitochondria. These RNAs may induce disease by generating defective mitochondrial DNAs, resulting in the disruption of the fungus' cytochrome oxidase respiratory system (Rogers, Buck & Brasier, 1987; Charter, Buck & Brasier, 1993). Production of the hydrophobic protein and putative wilt toxin, cerato-ulmin, is also reduced in d^2-infected isolates (Sutherland & Brasier, 1995). Overall, the phenotype of degenerate d^2-infected colonies resembles that of induced senescence. Several other *O. novo-ulmi* viruses also appear to be mitochondrially based. All these mitochondrially based viruses probably have mtDNA rather than nuclear DNA coding sequences (Hong *et al.*, 1998). Mitochondrial rather than nuclear transformation protocols may therefore be required to achieve experimental transformants equivalent to those achieved in *C. parasitica* with CHV1. Such mitochondrial transformation experiments are now in progress. However, non-mitochondrially based viruses have also been shown to exist in *O. novo-ulmi*. These may provide a nuclear route to viral transformation of *O. novo-ulmi* should the direct mitochondrial transfection and transformation route prove unsuccessful.

THE FUTURE

Viruses occur in many fungal pathogens and there is evidence that they can exert natural control of some plant diseases. However their exploitation for artificial disease control is still in its infancy. Overall, different systems, such as the Dutch elm disease and chestnut blight systems, or the *Rhizoctonia*, *Gaeumannomyces* and *Sclerotinia* systems, exhibit rather marked differences in fungal viruses, vc systems, reproductive strategies and disease dynamics. For this reason, it is unlikely that any one pathosystem can model for another, except at the level of general principles such as the likely impact of higher or lower levels of vc diversity on virus spread. Each system will almost certainly need detailed investigation its own right.

Although fungal viruses have relatively simple genomes, in order to exploit them for control more will need to be learned of the genomic structure of the different types of fungal viruses, their mechanisms of interaction with their fungal hosts including latency, the nature of fungal virus - fungal host recognition processes and the potential to bypass fungal vc systems by manipulating either the fungus or the virus. Eventually, the door may be open to the construction of viruses, infectious transcripts and 'magic bullets' designed to target particular pathogens.

Transferring whole viruses or selected viral genes between fungal species may be one way of enhancing or modifying viral effectiveness (cf Brasier, 1986). Experimental transfer of CHV1 to close relatives of *C. parasitica* has already been achieved with moderate success (Chen *et al*., 1996). Viruses are known to occur in two *O. novo-ulmi* relatives, *O. ulmi* and the recently discovered Himalayan Dutch elm disease fungus *O. himal-ulm*i. Hence these could be experimentally transferred to *O. novo-ulmi*. Another approach may be to design mycoviruses that can disrupt the metabolic (or signal transduction) pathways underlying pathogenesis in particular target fungi (Nuss, 1996); or viruses that disrupt the functioning of target's cytochrome oxidase system, inducing premature senescence. Strategically, it might eventually be feasible to design viruses to counter major external threats. An example might be the serious threat posed to European oak forests by the North American oak wilt fungus, *Ceratocystis fagacearum*.

In addition, exploitation of fungal viruses for biocontrol will depend upon the development of ecologically sound virus release strategies. This will require an equally thorough understanding of the ecological genetics of target pathogen populations and the likely effects of viruses on pathogen fitness, pathogen population dynamics and pathogen population structure. It is inevitable that some experimental releases of wild-type or modified viruses will fail or be only partially successful, but with appropriate monitoring, such releases should enhance our understanding of the practical and biological limitations involved. Fungal viruses may be of particular utility in situations in which the fungal pathogen and plant host are severely out of balance, as with epidemics caused by aggressive introduced pathogens. In these situations pathogen populations may also tend to be of low vc or other genetic diversity and therefore more easily targeted. Viruses could also be deployed as components of integrated control programmes, enhancing the effectiveness of the other control elements in a system. With Dutch elm disease in North America, for example, the main bark beetle involved, *Scolytus multistriatus*, is a poor vector (Webber, 1990). Successful deployment of fungal viruses could exploit this factor further and might perhaps induce a switch from an epidemic to a more sporadic or endemic level of disease. Deployment of viruses in the context of a higher intrinsic level of elm resistance could also enhance their effectiveness (Brasier, 1986).

The deployment of wild-type viruses against their natural, presumptively co-evolved fungal host fits fairly well within the classical biological control concept of introducing a natural enemy to control a pest. So too, perhaps, does a strategy of releasing a pathogen transformed with its 'own' virus; indeed this might even occur naturally as a random process. The deployment of substantially genetically modified viruses or designer magic bullets, however, would raise additional environmental issues needing careful and objective assessment, in particular the risk of transfer to other organisms. There is no doubt that viruses and plasmids are occasionally transferred between different, closely related fungal species in the field and that transfer between more distantly related taxa is also possible via rare genetic events (Brasier, 1995). The potential for unusual gene transfer among bacterial species is already suggested to be high (eg Groisman & Ochman, 1996; Lawrence & Roth, 1996). On the other hand the intracellular nature of fungal virus transmission and the probable high level of host specialisation in fungal viruses (Buck, 1998; Milgroom, 1998), together with other genetic and ecological factors, may reduce the likelihood of such events occurring or of the outcome being biologically meaningful. The potential social gains in terms of environmental protection and disease control, such as the restoration of mature elm and chestnut populations across Europe and North america, could be considerable. Nonetheless, a careful case-by-case approach, building on detailed knowledge of the ecology and genetics of the fungal interactions involved, is necessary to provide the confidence that such control methods are environmentally feasible and acceptable.

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Target technology - bring the insect to the insecticide not the insecticide to the insect

O Jones
ArgiSenseBCS Ltd, Treforest Industrial Estate, Pontypridd, Mid Glamorgan, CF37 5SU, UK

P Langley
Insect Investigations Ltd, School of Pure and Applied Biology, University of Wales, Cardiff, P.O. Box 915, Cardiff, CF1 3TL, UK

ABSTRACT

Inefficiencies in spray applications have encouraged the development of Target Technology where the pest insect is attracted by olfactory and visual cues to an insecticide treated target device where they receive either a lethal dose of conventional insecticide or a sterilising dose of an appropriate IGR. Examples of the successful application of the technology with Tephritid fruit flies, Tsetse flies, nuisance flies and glasshouse pests are given in this paper.

INTRODUCTION

It has long been known that the amount of insecticide active ingredient that actually makes contact with a target insect, as a percentage of that which is sprayed, is very small. Indeed in most cases, less than 1% ever gets to its intended target (Matthews, 1992) because of the atomisation process, the effects of spray drift, plant coverage, and degradation processes. This must be a very inefficient way to utilise any active ingredient, with the consequential need to over-dose and thus needlessly contaminate the environment.

Much work has been done over the last 30 – 40 years to develop non-toxic alternatives to conventional insecticides including microbial, botanical, biological and biotechnical pest control technologies. These however, have not replaced the use of man-made traditional insecticides to any significant extent although they have found many important niches in Integrated Pest Management practices. One alternative technology that has shown great promise involves the use of semiochemicals and pheromones in particular. The use of pheromones as highly specific lures in traps designed for monitoring insect pests has become very well established in most countries and such systems have undoubtedly lead to a more rational use of insecticides in many crops where spray timing is crucial. Attempts to use them as control technologies by themselves, however, have not been so successful. Mating disruption of certain lepidopteran pests using sex pheromones is a good example of the use of pheromones for controlling pest populations but the technique is not universally applicable to all lepidopteran species. Similarly, attempts to use pheromones and other semiochemicals in traps to control pest populations through mass trapping have also been unsuccessful in the majority of cases.

There are several reasons why mass trapping is not a viable option on a large scale. These include:

- lack of attraction of females especially if the attractant source used is a lepidopteran sex pheromone,
- highly inefficient traps
- problems of high insect populations and trap saturation,
- the need for a high density of traps per unit of surface area making the technique too costly.

Although there are some examples of the successful use of mass trapping as a means of controlling insect pests, it is only when the short-comings of mass trapping have been overcome through the development of Target Technologies that this form of insect control can begin to make an impact on pest management thinking.

TARGET DEVICES FOR CONTROLLING THE ORIENTAL FRUIT FLY (*BACTROCERA DORSALIS*)

Although generally the attraction of males only to traps or target devices is not sufficient to control insect pest population, the attraction of *B. dorsalis* males by its para-pheromone methyl eugenol is so potent that the phenomenon has been exploited in target devices for the fly's annihilation in several countries. Fibrous blocks containing methyl eugenol and an insecticide such as Naled (dibrom) have been used as target devices for male, *B. dorsalis*, in many eradication programmes. The first successful attempt at eradicating *B. dorsalis* by male annihilation was made by Steiner *et al.* (1965) on the island of Rota in the Marianas. They used 5% by weight of an insecticide in Methyl Eugenol which was used to saturate 5 cm fibreboard squares so that each held 24 g of the mixture. These fibreboard squares were then thrown out of an aircraft over uninhabited areas at given rates and re-application intervals to achieve eradication in about 6 months.

This technique was then adopted by the Japanese government in an ambitious eradication campaign against Oriental fruit fly in the Ogasawara Islands. Over a period of ten years, they were able to eradicate the fly from all the islands in the archipelago from Amami in the North to Okinawa in the South (Koyama *et al.*, 1984).

More recently the same technique has been used successfully to eradicate *B.dorsalis* or its sub-species following accidental introductions of the species into Northeastern Australia (Broughton *et al.*, 1998) and the island of Mauritius (Seewoorthrum *et al.*, 1998).

The success of this technique was undoubtedly based on the fact that methyl eugenol is very attractive indeed to *B. dorsalis* and is capable of attracting a sufficiently high percentage of males to the insecticide-treated target devices to leave the females unfertilised. No other para-pheromone has been shown to produce the same effect when used alone as the lure; in most cases some other attractant has also been used together with the para-pheromone in order to attract the females.

TARGET DEVICES FOR CONTROLLING THE OLIVE FLY (*BACTROCERA OLEAE)*

Before the development of target devices for olive fly (*Bactrocera oleae*) many attempts were made at mass trapping this species. Yellow traps coated with non-drying adhesive were used successfully on both a small and a large scale for controlling olive fly populations. However, the high density of traps used, required in some cases as many as five traps per tree, which made the technique uneconomic and very destructive to the natural enemy populations in those olive groves (Economopoulos, 1979; 1980).

It was then discovered that the number of traps required could be reduced substantially if the traps were baited with an olfactory attractant, either a food attractant, a sex pheromone, or both. Experiments carried out in Italy demonstrated that, with one yellow trap per tree baited with ammonium carbonate and the sex pheromone of *B. oleae*, very acceptable results were obtained if the olive harvest was good and the resident population of olive fly was low. However, the results obtained in those years when the population of olive fly was high and the olive harvest was low were not satisfactory (Delrio, 1985). Traps baited in a similar way, but used at a density of 1 per 9 trees, when used on a very large scale in Greece, lead to a reduction in the number of insecticide treatments required to control olive fly from 3 to 1 (Broumas *et al.*, 1983).

Such results were never sufficiently effective for the technique of mass trapping to be adopted on a widespread commercial scale. Trap saturation, and high maintenance problems have been overcome to a large extent, in the case of the olive fly, by abandoning sticky traps and turning instead to target devices treated with insecticides to kill the flies on contact. In this way, problems of trap saturation have been overcome because the insect, once having picked up a lethal dose of insecticide from the target device, flies or walks away from it until the toxic effects of the insecticide manifest themselves. Changing to targets with grey, green or brown colours, which are less attractive to natural enemies, instead of yellow also diminishes possible detrimental effects on beneficial insect populations.

Work in Greece over the last ten years, and more recently in Spain, has been aimed at overcoming the short-comings of mass trapping using sticky traps through the development of target devices, which carry an insecticide for killing the attracted flies instead of adhesives. The target devices used in most of the large scale trials undertaken in Greece consisted of plywood rectangles (15 x 20 x 0.4 cm) dipped into appropriate concentrations of the pyrethroid insecticide Deltamethrin for a sufficiently long period of time to saturate the wood with the insecticide solution. These devices were baited with ammonium salt dispensers (food attractant) and one target in 3 or 5 was also baited with a sex pheromone dispenser.

Fewer sex pheromone dispensers than food attractants were thought necessary because of the difference in their range of attraction. That of the sex pheromone was shown in earlier experiments to be 60 - 80 m, while that for the food attractants was only 15 - 20 m. Great logistical problems had to be overcome during the period of device installation in June and July, especially in years where over 2,000,000 trees were treated. As the controlled release devices for the food and sex attractants became more advanced, it was possible to install the target devices during early summer and reasonably expect them to last until late autumn, when olive fly populations reduce in importance through decreasing temperatures and the olives are harvested. The effectiveness of the target devices was monitored throughout the periods of operation and olive fly populations were also monitored by the use of traps and samples of olive fruit for periodic examination of damage levels. Samples of the target devices were also taken back to the laboratory to verify by bioassay that the insecticide content of the plywood boards was still sufficient to kill the fly.

Results over five years from the area-wide application of these target devices in Greece can be summarised as follows:- Fly populations as measured by McPhail traps were consistently lower in target-device treated areas compared with conventionally treated controls. The average number of bait sprays that had to be used in target treated areas during the early years of the programme (1984/1985) were 1 as opposed to 2.5. No supplementary bait sprays were required in later years in the target-device treated areas. In most years, fruit infestation was lower than or equal to that in the controls where conventional bait sprays were applied (Haniotakis *et al.*, 1991).

The target device method of controlling *B. oleae* was, therefore, very effective as a method of eliminating insecticide bait sprays resulting in significant increases in beneficial insect numbers in target-device treated areas (Paraskakis, 1989). However, for the method to work to its greatest effect, it has to be applied over a large area. In small plots, large-scale adult movements over short distances can significantly over-ride the effects of the devices. Similarly, when the system fails to contain pest populations, complementary measures are almost invariably required, significantly affecting the cost effectiveness of the technique.

In Spain, similar target device technology has been tested on a relatively large scale since 1992. The concept is the same as that used in Greece but, instead of using wooden boards, cloth targets are soaked in Deltamethrin. The devices have been baited with long life lures such as those used on monitoring traps, or have been baited repeatedly with sprayable protein and microencapsulated pheromone. The latter need to be replenished several times during the season and, although the materials cost very little, the technique is still labour-intensive. With long life lures, the up-front costs are greater but require very little maintenance thereafter during the rest of the season. In areas as large as 400ha, very satisfactory results have been obtained in most years.

This method of managing *B. oleae* populations, although more labour intensive generally, will nevertheless be pursued in most olive growing countries since legislative and environmental pressures will eventually restrict the broad scale use of bait sprays.

TARGET DEVICES FOR CONTROLLING TSETSE FLIES

Lure and Kill target devices for tsetse fly (*Glossina* spp.) have been used successfully in various parts of sub-Saharan Africa (Vale *et al.*, 1985) for a number of years. The technique has been successful because both sexes of the fly must feed frequently on vertebrate blood in order to satisfy all their dietary needs including the requirement for water. Consequently, the flies are extremely well-adapted to locating their hosts using both visual and olfactory stimuli. Incorporation of such stimuli into target devices treated with insecticides provides an effective means of removing adults of both sexes from the population. Additionally, tsetse are viviparous and each adult female produces only a few offspring during her lifetime. Consequently it is only necessary to remove a small proportion of the adult population each day to have an impact on their numbers. Tsetse are also much more sensitive to insecticides than other flies.

Preliminary trials with insecticide treated target devices were carried out on isolated populations of *G. m. morsitans* and *G. pallidipes* on a 4.5 sq. Km island in Lake Kariba, Zimbabwe (Vale *et al.*, 1986). Twenty insecticide-treated targets baited with acetone and octenol, two components from the odour of host animal breath, were used in this trial and the targets killed about 2% per day of the *G. m. morsitans* and 5% per day of the *G. pallidipes*. The population declined rapidly and disappeared in 9 months and 11 weeks respectively (Vale *et al.*, 1985). Following this, insecticide treated targets were used to eliminate natural populations of these two species in the Rifa Triangle, an area of 600 sq Km in the Zambezi valley where re-invasion pressure from the neighbouring wildlife area was significant (Vale *et al.*, 1988). Odour baited traps and targets are now in widespread use for tsetse control in many parts of Africa. Their cost effectiveness is enhanced by the persistence of modern pyrethroids and the very small doses required to kill tsetse.

TARGETS WHICH STERILIZE RATHER THAN KILL

A recent development in the use of target devices for controlling tsetse flies involves the use of insect sterilising agents instead of insecticides on the target device itself. Langley & Weidhaas (1986) argued that sterilisation of both sexes of tsetse in a population at a certain rate would be more effective at suppressing that population than simply killing them at the same rate. Their explanation for this goes as follows: Killing females only would be as effective as killing both sexes, since it is only females that reproduce. It follows therefore that to sterilise females only would be as effective as killing both sexes. Hence, the sterilisation of males as well as females would be a bonus. The nature of this bonus is that sterilized males will mate with normal females and sterilize them. They also calculated that the arc of influence of a sterilising device should be greater than that of a target which simply kills flies. In theory also, a sterilising device should reduce the risk of behavioural resistance developing against the device since attracted sterilised flies would mate with unattracted individuals.

INSECT GROWTH REGULATORS (IGRS) AS STERILIZING AGENTS

Juvenile Hormones and their Mimics

The juvenile hormones and their mimics have long been known to disrupt metamorphosis in insects if applied to the larval stages. They are also able to disrupt embryogenesis and therefore prevent egg hatch. The juvenile hormone mimic pyriproxifen has proved to be very useful as a sterilising agent for tsetse fly females (Langley *et al.*, 1990a). When a female makes contact with a target device treated with a suitable formulation of this compound, it is absorbed through the female's cuticle and is transported to the larva *"in utero"*. The third instar larva appears to be normal but, after pupation, metamorphosis is disrupted. Only very small amounts of pyripoxifen are required and a single treatment will ensure that the female is effectively sterilised for life. Laboratory studies have also shown that males making contact with a treated surface can transfer sterilising doses to females when they mate (Langley *et al.*, 1990a). Field trials in Zimbabwe have shown that pyriproxifen can be used as an alternative to conventional insecticides in target devices for tsetse control (Hargrove & Langley, 1990).

Juvenile hormone mimics are also very effective on Hemipterans, such as *Rhodnius prolixus*, a member of the group of disease vectors in South America. These mimics not only disrupt metamorphosis, but sub-lethal doses which permit metamorphosis to occur, will then prevent the resulting adult females from producing viable eggs (Langley *et al.* 1990b). Also the greenhouse whitefly (*Trialeurodes vaporariorum*) can be controlled using target devices consisting of a yellow cloth or plastic sheet treated with pyriproxifen and suspended amongst whitefly host plants in a greenhouse (Langley 1998). Such targets gave protection for a whole season without replacement or re-treatment with the IGR. It has recently been found that such devices can be used in conjunction with the parasitoid wasp *Encarsia formosa*, by careful positioning of such targets so that they maximise their effect on the whitefly but minimise their effect on the parasitoid (Senior, 1998).

Chitin Synthesis Inhibitors (CSIs).

Other compounds such as those that interfere with the synthesis of chitin can also be used on target devices. In addition to their ability to stop insect larvae from moulting, they can prevent the adults of some species from producing viable eggs. These compounds are highly effective 'sterilants' for Dipteran nuisance flies. The CSI Triflumuron, when mixed with sugar and coated on visually attractive black and white target devices, has been successfully used to control a population of the lesser housefly (*Fannia canicularis*) in a commercial rabbitry in the UK during the summer of 1995 (Langley, 1998). Similarly, populations of the common housefly (*Musca domestica*) were suppressed in a poultry house in India (Howard & Wall, 1996).

A recent adaptation of target technology involving treatment of yellow cloth targets with a mixture of sugar and triflumuron has been investigated for the control of those fly species (Chironomidae and Psychodidae) whose larvae graze the biofilm on sewage filter beds. They are a necessary part of the system, without which the filters can clog. The psychodids are poor fliers and rarely constitute a problem. However, if the chironomid midges *Limnophyes minimus* and *Metriocnemus hygropetricus* are present in excess, the adults constitute a nuisance in nearby residential areas. Most conventional insecticides cannot be used for fear of environmental contamination; *Bacillus thuringiensis* var. *israelensis* is one of the very few products approved and currently available for use against the larvae of these pests in water treatment plants. In an attempt to develop non-polluting methods of managing these pests, target devices were deployed against the adult stages. Although the adult stages do not normally feed and have vestigial mouthparts, Langley (1998) found that they will feed on a surface coating of dried sucrose and, consequently, they will imbibe triflumuron mixed with it. This seriously reduces their ability to produce viable eggs. It has also been found that the attraction of the midges, and especially the females, to yellow colour can be enhanced through the use of low wattage, white fluorescent light to illuminate the yellow cloths between dusk and dawn. Thus, by targeting the adult midges an effective nuisance fly control method has been developed which is non polluting to the waterways downstream of the filter beds. It is hoped that the method will soon be the subject of a registration application for use in the UK.

CONCLUSIONS

Target technology is a relatively new concept that has developed significantly in recent years. Two main factors have accounted for much of the progress. The chemical ecology of insects is now much better understood and olfactory and visual attractants are much better defined in a number of insect species. In addition, we now have very good contact insecticides and IGRs that are suitable for use on target devices. Clearly much more research and development will be required to optimise and extend the use of target devices. However, with the clear environmental benefits that come from their use, pressure to develop new solutions to pest problems through target technology will increase. Since the amount of insecticide involved in such techniques will be relatively small, companies will need to change their marketing approach from one of supplying 'chemicals' to one of supplying 'solutions' to pest control problems. This is a paradigm shift in our approach to pest management and it will be interesting to see whether all stakeholders in the pest management arena will rise to the challenge.

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A β 1-3 glucan, specific to a marine alga, stimulates plant defence reactions and induces broad range resistance against pathogens.

J M Joubert, J C Yvin
Laboratoires GOEMAR, Avenue du Général Patton, 35400 Saint Malo, France

T Barchietto, J M Seng
BIOTRANSFER, 41 rue Emile Zola, 93100 Montreuil-sous-Bois, France

B Plesse, O Klarzynski, M Kopp, B Fritig,
Institut de Biologie Moléculaire des Plantes du CNRS, 12 rue du Général Zimmer, 67000 Strasbourg, France

B Kloareg
Centre d'Etudes d'Océanographie et de Biologie Marine du CNRS, BP 74, 29682 Roscoff, France

ABSTRACT

"Laboratoires Goëmar" have identified, isolated and industrially extracted from a brown alga a natural molecule, a ß 1-3 glucan (code GL32) which stimulates plant defence reactions and induces resistance to diseases. GL32 consists of several units of D-glucopyranosides linked by 1-3 bonds and branches linked by 1-6 bonds. Studies show that GL32 is harmless to man and the environment. Treatment of tobacco, tomato and wheat cell cultures as well as wheat seedlings with GL32 induced metabolic changes typical of defence responses : early events (such as ionic fluxes, phosphorylations, oxidative burst), stimulation of the phenylpropanoid and lipid-derived pathways (leading to the signals salicylic acid and jasmonates, respectively), and production of PR-proteins (known for their high antimicrobial potential). While GL32 had no direct antifungal activity, spraying with GL32 at low concentrations (20 to 50 $g.ha^{-1}$) protected efficiently wheat seedlings against infection by *Septoria tritici* and *Erisyphe graminis*. Furthermore, when combined with synthetic fungicides, GL32 increased their efficiency at low concentrations. The origin of GL32, its protection potential against important diseases and its mode of action (stimulation of the plant's natural defence responses) open a new path to plant protection for farming procedures that respect the environment.

INTRODUCTION

Treatments that stimulate the natural defence responses of plants offer new potential for disease control. In recent years considerable progress has been made in the molecular dissection of natural resistance responses induced by the pathogens themselves, particularly the phenomena of localized acquired resistance (Hammond-Kosack & Jones, 1996; Fritig *et al.*, 1998) and systemic acquired resistance (Ryals *et al.*, 1996). These efficient defence mechanisms are induced only after a specific recognition of the pathogen or of pathogenic component(s) by the plant. However, a number of studies have shown that external application of various compounds can mimic at least partially, these pathogen-induced mechanisms. Indeed a small number of compounds have been tested for their ability to induce resistance to diseases in laboratory, glasshouse and field experiments (Lyon *et al.*, 1996). Among these compounds are salicylic acid (SA), fatty acids and jasmonates that are natural signals likely to be produced during a pathogen-induced defence, but also recently described synthetic elicitors such as 2,6 dichloroisonicotinic acid and benzothiodiazole (Ryals *et al.*, 1996). There are only few reports on resistance responses induced by natural elicitors, for instance yeast-derived elicitors (Lyon *et al*., 1996). In the present report we describe the efficient resistance responses induced under laboratory as well as field conditions by a glucan isolated from a marine alga and we show that this natural molecule is a potent stimulator of the typical defence responses known to occur in natural resistance mechanisms.

GL32 PRESENTATION

"Laboratoires GOEMAR" have extracted a β 1-3 glucan (code GL 32) from marine brown algae of the Pheophyceae class, notably Laminariales. GL 32 molecule has a β -D glucopyranose structure comprising 1,3 linkages and a low level of 1,6 branchings, with certain mannitol reduction ends (Percival & Mc Dowell, 1967). The production process, based on a water extraction procedure followed by a purification phase on membrane and concentration by diafiltration, avoids use of any organic solvent and thus any residual chemical contamination.

Chemical and physical properties

Product category :	Plant activator
Structural formula :	β 1-3 glucan
Code number :	GL 32
EEC number :	232-712-4
CAS number :	90008-22-4
Molecular formula :	$(C_6 H_{12} 0_6)n$
Molecular weight :	4500 - 5500
Appearance at 25°C :	white odourless powder
Melting point :	$[\alpha]^{18}{}_{D}$ - 11,9° (C = 2.1)
Solubility in water at 25°C :	5% soluble max
Solubility in organic solvent :	insoluble

Toxicology

Acute oral LD_{-50} rat :	> 2000 mg/kg
Acute dermal LD_{50} rat :	> 2000 mg/kg
Skin irritation rabbit :	non irritant for the skin directive N° 93/21/EEC
Eye irritation rabbit :	non-irritant for the eye directive N° 93/21/EEC
Sensitization using the Magnusson and Kligman maximisation test :	substance is free of any sensitising capacity
Mutagenicity :	no mutagenic potential
Carcinogenicity :	no carcinogenic potential

MATERIALS AND METHODS

For trials run under controlled conditions in the laboratory, two-week-old seedlings (BBCH13) of winter wheat cv. Scipion (10 seedlings per pot) were treated with GL32 or distilled water (control) in the presence of 0.1% Tween 20 as surfactant. After several days of incubation in a controlled environment (20°C, 16h photoperiod), treated and untreated plants were inoculated with conidial suspension ($1x10^5$ spores.ml^{-1}) of *Septoria tritici* strain A, as described by Eyal & Scharen (1977) and thereafter placed for 96 h in a humidity chamber at 20°C. Severity of the disease (estimation of the infected leaf areas) was assessed visually 28 days after inoculation.

Winter wheat field trials have been carried out with 4 replicates. These trials were set up in accordance with CEB method n°189 A.N.P.P. (1996). Growth stages were described according to the BBCH scale. GL32 was sprayed with a volume of 250 $l.ha^{-1}$ at the BBCH 30 stage.

Visual assessments of the leaf area were observed at several times and the efficiency results expressed using the formula :

$$\frac{\text{\% leaf area attacked on untreated - \% leaf area attacked on treated}}{\text{\% leaf area attacked on untreated}}$$

The potential of GL32 to stimulate plant defence responses was assayed on tobacco BY, tomato MSK8 and wheat cell cultures as well as wheat seedlings. Suspension cells were subcultured and incubated 6-7 days later with GL32 applied at concentrations from 0.01 to 0.2 $g.l^{-1}$. Wheat seedlings were treated by spraying with aqueous solutions of GL32 or leaf pieces were floated on MES buffer containing GL32. A number of biochemical markers typical of induced plant defence responses were assessed : extracellular alkalinization of the medium measured according to Felix *et al*. (1993), production of H_2O_2 according to Jabs *et al*. (1997), lipoxygenase activity assayed according to Bohland *et al*. (1997), activities of phenylalanine ammonia lyase (PAL) and caffeic acid O-methyltransferase (COMT) assayed according to Legrand *et al*. (1976), salicylic acid (SA) levels according to Baillieul *et al*. (1995), detection of induced PR-proteins by western blotting using antibodies against several families of tobacco PR-proteins (Stintzi *et al.,* 1993; Fritig *et al*., 1998).

BIOLOGICAL ACTIVITY OF GL32 UNDER CONTROLLED CONDITIONS

Activity rates of GL32 to protect wheat against *Septoria tritici*

Three days after GL32 treatment in the laboratory, the plants were inoculated (as described in Materials and Methods). A typical experiment displaying the response curve in relation to dose rate is illustrated in Figure 1. GL32 reduced the symptoms of the disease due to *Septoria tritici* in a rate-dependent manner. The optimum efficiency (about 73%) was obtained with the concentration in the range of 0.002 $g.l^{-1}$.

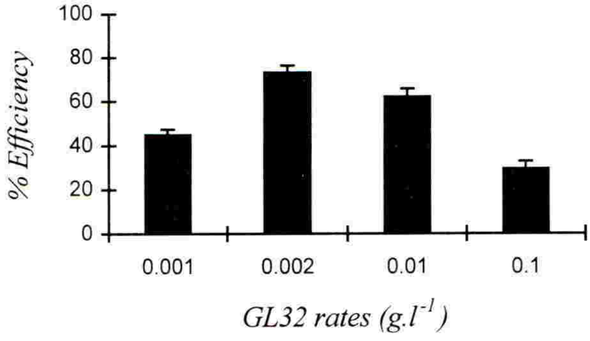

Figure 1 : Rate-dependent effect of GL32 in protecting wheat against *Septoria tritici*.

GL32 has no direct antifungal activity

The *in vitro* sensitivity of the *S. tritici* strain A to GL32 was determined using the microtitre plate red technique developed by Pijls *et al*. (1994). GL32 did not exhibit any *in vitro* fungitoxic activity on fungal growth of *S. tritici*, whatever the concentration tested (0.001 to 10.0 µg a.i.ml^{-1}).

GL32 induces broad range resistance

Studies conducted in controlled conditions demonstrated a good efficacy of GL32 in protecting wheat against *Erisyphe graminis* f. sp. *tritici*, *Septoria nodorum*, *Puccinia recondita* and *Fusarium graminearum*. Preliminary studies also revealed a good efficiency of GL32 against *Helminthosporium teres* on barley, *Plasmopara viticola* on vine, *Magnaporthe grisea* on rice and *Venturia inaequalis* on apple. GL32 appears to be a broad-spectrum plant protection inducing compound with respect to the diversity of both the protected plant species and the pathogens that are inhibited.

GL32 is a potent stimulator of natural defence responses

Cultured plant cells have been widely used as model systems, to study the recognition and the signal transduction chain of molecules of various origins suspected to induce plant defence and plant resistance. Thus, in our investigations on the mode of action of GL32-induced plant protection, we have used tomato, wheat and tobacco suspension cells, with an emphasis on the latter system for which the largest array of defence components are known. It was found that GL32 was an efficient stimulator of defence responses in tomato, wheat and tobacco. As an example, Figure 2 illustrates the strong induction of the phenylpropanoid enzyme PAL in GL32-treated cells. In these cells we also observed a strong response in alkalinization of the medium, production of H_2O_2, stimulation of COMT and lipoxygenase activities, accumulation of SA (an important signal of induced resistance) and of PR proteins (data not shown). GL32 appeared to be a plant stimulator as active on tobacco as the proteinaceous elicitors "elicitins" (Baillieul *et al.*, 1995), but with the major advantage of stimulating defence responses without causing any cell death. The GL32-induced defence responses were suppressed in the presence of the kinase inhibitor staurosporine, showing that, as for all efficient elicitors, early phosphorylation events are involved in its activity.

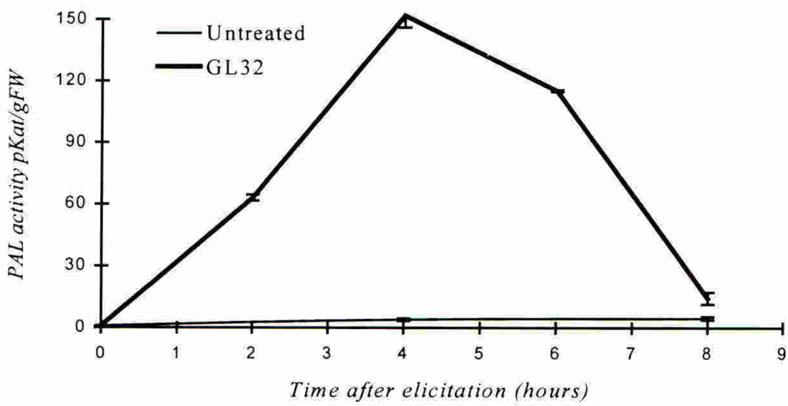

Figure 2 : Induction of phenylalanine ammonia-lyase (PAL) in GL32-treated tobacco cells

Kinetics of GL32-induced resistance in wheat

A typical experiment performed as described in Materials and Methods is illustrated in Figure 3. The results showed that the level of protection of wheat seedlings was dependent on the period of time between treatment with GL32 and inoculation. Thus, the highest level of protection was obtained for plants pretreated with GL32, 7 days before *S. tritici* inoculation. These results are consistent with the fact that GL32 is a stimulator of plant defence reactions.

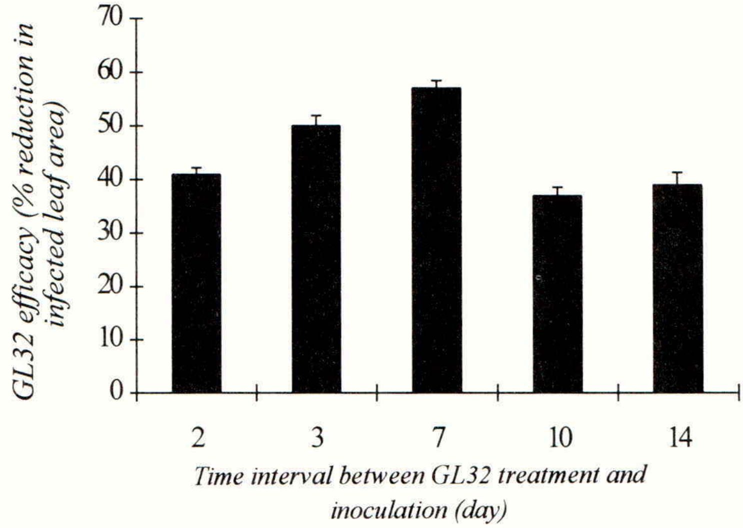

Figure 3. Kinetics of resistance development in wheat after GL32 treatment.
(Efficacy of treatments were assessed by determining the infected areas of the first leaves at 28 days after inoculation. At that time 95 % of the leaf area of untreated plant was infected).

AGRONOMIC INTEREST

Activity rates

Three field trials were carried out in France, in 1998, to estimate the efficiency of GL32 treatment in protecting wheat against disease caused by *Septoria tritici* under conditions of natural contamination. The disease was noted 30 days after treatment.

Whatever the rates, GL32 displayed an efficiency exceeding 50%, but the optimum rate was contained between 20 and 60 $g.ha^{-1}$ (Figure 4) and induced protection up to 60%. These trials confirmed the efficiency of GL32 observed in controlled conditions.

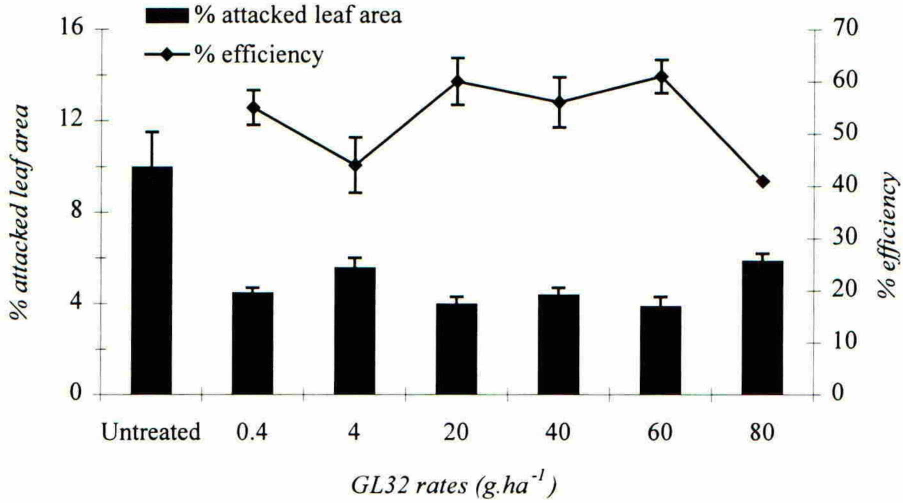

Figure 4 : Effects of GL32 on disease caused by *Septoria tritici* on winter wheat

Lasting and systemic effects of GL32

In other field trials, GL32 was sprayed (40 $g.ha^{-1}$) at BBCH 30 and its effects compared with those of the fungicide tebuconazole. Visual assessments of *Septoria tritici* disease were carried out on different leaf levels, according to dates (Treatment + 30 days, + 45 days, + 60 days, + 75 days).

GL32 (40 $g.ha^{-1}$) induced significant protection against *Septoria tritici* with lasting effects for 30 to 60 days after treatment (Table 1).

Table 1 : Lasting effects of GL32 on *Septoria tritici* disease of wheat

Assessment dates	% attacked leaf area :		
	Untreated	GL32 (40 $g.ha^{-1}$)	Tebuconazole (250 g $a.i.l^{-1}$)
Treatment + 30 days	10 1.5	4.4 ± 0.3	5.9 ± 0.3
Treatment + 45 days	17 2	10.1 ± 0.9	11.1 ± 1.0
Treatment + 60 days	11 0.9	7 ± 0.5	7 ± 0.3
Treatment + 75 days	78 5	70.3 ± 7.0	77.7 ± 5.0

Forty-five days after treatment, the leaves were not unfolded when GL32 was sprayed at the stage BBCH30 and thus, these leaves did not receive the product. Despite this, we noted protection efficiency on these leaves. GL32 induced resistance in the plant during a period of about 45 days. Similar effects were observed on vine infected by*Plasmopara viticola* : after GL32 treatment the new leaves which were not unfolded at the time of the treatment, became resistant to an attack by *Plasmopara viticola* to the same extent as the leaves treated with GL32.

Efficacy of GL32 used alone or in combination with fungicides

In other experiments we studied the efficacy of GL32 and of the fungicides, epoxiconazole, tebuconazole, fluzilazole and chlorothalonil alone, or in mixture, on *Septoria tritici* on wheat in controlled conditions, sprayed 3 days before inoculation with a conidial suspension *of S. tritici* strain A. Severity of the disease was visually assessed 28 days after inoculation.
When used in mixture with fungicides, GL32 clearly enhanced their protectant activity against *Septoria tritici* blotch of wheat (Table 2).

Table 2 : Performance of GL32 used alone or in mixture with epoxiconazole, tebuconazole, fluzilazole and chlorothalonil against disease caused by *Septoria tritici* strain A, in controlled conditions

Treatments	Rate g a.i. l^{-1}	Efficacy (% of the control) :	
		alone	+ GL32 (0.02 g. l^{-1})
GL 32	0.02	10.1 ± 1.2	
Epoxiconazole	0.025	45.2 ± 0.8	56.2 ± 1.0
	0.05	72.5 ± 0.5	81.8 ± 0.6
Tebuconazole	0.05	34.4 ± 1.3	45.0 ± 1.3
	0.1	59.6 ± 1.0	70.2 ± 0.7
Fluzilazole	0.05	35.7 ± 1.1	45.3 ± 1.5
	0.1	61.1 ± 0.5	69.4 ± 0.7
Chlorothalonil	0.37	28.3 ± 1.8	36.9 ± 2.0
	0.75	49.4 ± 1.2	58.8 ± 1.1

CONCLUSIONS

GL32 is a natural β 1-3 glucan molecule, harmless to man and the environment, that stimulates the natural plant defence reactions through an original mechanism in which both the salicylic acid and lipid (fatty acids and jasmonates) pathways are stimulated, leading to protection against diseases caused by fungi and bacteria. GL32 was found to confer a long lasting protection in cereals, for instance a protection during 45 days in wheat against *Septoria tritici* . The experimental results also suggest that GL32 has potential in mixture with fungicides, by increasing their efficacy against diseases. This β 1-3 glucan molecule offers great potential in crop protection strategies, oriented towards efficacy and preservation of the environment.

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Potential of fuzzy logic in crop protection decision making

R P Blackshaw, L Winder
Seale-Hayne Faculty, University of Plymouth, Newton Abbot, Devon, TQ12 6NQ, UK

M Lefley
School of Design, Engineering and Computing, Bournemouth University, Poole, Dorset, BH12 5BB, UK

ABSTRACT

This paper describes a decision support system which uses an inference engine to provide advice based on an evaluation of information using fuzzy logic. An example is given where a previously published decision tree which assessed the risk of cereal aphid outbreaks in summer is used as the basis for a fuzzy decision support system. The output from this system is reported and it is argued that this approach may be more appropriate than more deterministic crop management decision-making which is often reliant on quantitative information which is either unavailable or of questionable accuracy.

INTRODUCTION

The introduction of the economic threshold (Stern *et al*., 1959) provided a rational underpinning for crop protection decisions. In essence a comparison between the anticipated financial benefits and the cost of spray treatment is made. Norton (1976) used the following mathematical expression to illustrate this approach:

$$\theta = \frac{c}{p.d.k}$$

c is the cost of control, *p* the unit value of the crop, *d* the yield loss per pest and *k* the expected proportional mortality from the selected insecticide dose. Calculations using this expression provide an estimate of break-even or threshold pest populations.

However, such calculations may give a spurious air of precision because they yield a number; in reality, even calculations with few parameters are prone to error. In many cropping situations the final price (*p*) is unknown until after harvest, the yield loss per pest (*d*) may depend on temperature and the expected mortality (*k*) will depend on conditions, machinery and labour skill. There is also the assumption that the scientific or experimental data from which thresholds are derived is predictable; a perusal of research literature often reveals a series of not especially high correlations. Even if these parameters are estimated with a high degree of precision, their use is still dependent upon an assessment of pest numbers by monitoring. There is an assumption that the farmer or agronomist will accurately assess the pest population. This is often unreasonable given the sample size normally needed to accurately estimate insect populations, with the result that this approach is beyond the scope of most decision makers. Furthermore, there is evidence that monitoring counts of even large insects such as craneflies are subject to significant errors (Blackshaw, 1987).

Mumford & Knight (1997) identified 17 conditions that make the identification of economic thresholds uncertain, including market prices, duration of pest attack, weather conditions and variable natural control. Hence, the operational use of thresholds, particularly in species such as cereal aphids in temperate regions, is of little use because quantitative data are not accurate enough to parameterise threshold models. This can lead to advice to a farmer being given on the likely economic costs without reference to a specific threshold.

We argue in this paper that an alternative approach is needed with decision support given through a qualitative or 'heuristic' approach. If it is accepted that data input into forecasting is imprecise, then this problem should be addressed directly at the point of advice delivery through methods that simulate the thinking of an expert, rather than the application of a dubious mechanistic model.

Edwards & Cooley (1993) argue that an expert system requires more than factual knowledge before expertise can be displayed and that this additional knowledge consists of heuristics or 'rules of thumb' when interpreting factual knowledge. When advice is provided to farmers by experts they often adopt an heuristic approach where *".....rules of good judgement...."* (Harmon & King, 1985) are used when ambiguous or difficult decisions are made. Such a decision making process is difficult to incorporate into computer based expert systems (Durkin, 1994). To overcome the problem of imprecise data or uncertain information, we adopt an expert systems approach which incorporates fuzzy logic

Kennedy & Spooner (1994) define fuzzy logic as a *'multivalued logic which allows membership values along the continuum of values between true (1) and false (0)'*. This contrasts with 'classical' logic which requires a 'true' or 'false' answer. Fuzzy logic has the advantage that vague, missing or erroneous answers may be considered when decision making (Jamshidi *et al.*, 1993; Zadeh, 1996).

We present an example of a translation into fuzzy logic of an existing dichotomous decision tree addressing risks of cereal aphid outbreak in England (Dewar & Carter 1984).

MATERIALS AND METHODS

The expert shell 'Matcher' (Lefley, 1995), a Windows based system written in Visual Basic was used in the development of the support system. 'Matcher' adopts a probabilistic approach to describe the likelihood of an outcome and allows questions to be answered using a variety of question formats, forward chaining of questions and weightings. The system builder uses questionnaire answers as the basis of knowledge representation. New knowledge is entered directly by answering questions for a given conclusion. The shell allows questions to be answered using three question formats, namely:

SIMPLE. A question format where a single answer is selected from two or more options. A value is given by the system builder for selection of a 'yes' answer (e.g. +1) and a second value for a 'no' response (e.g. -1).

MULTIPLE. Responses correspond to one or more 'yes' or 'no' answers. A score is recorded for the question according to the user's response. For example, a 'yes' answer may be given a response value of +10 and 0 for a 'no' answer. This question type is useful for mutually exclusive responses.

MULTIPLE RATE. The response may be chosen from a series of choices which can include ambiguity; typically 'no', 'maybe not', 'don't know' 'maybe' and 'yes'. Each level of response is given a numerical value (e.g. -10, -5, 0, +5, +10). This question type may be used to incorporate an expert 'impression' regarding a given question.

The system is developed by setting response values and question weights which are chosen to reflect the importance of answers given. There are no set rules for these settings, but are assigned by the system builder according to the perception they have of the relative importance of questions. Values may be fine tuned to improve discrimination power during system development. The case-based decision system is based on a fuzzy distance measure, where comparison is made between the answers given for a new case entered by the user and a set of stored records (each record corresponding in this case to an evaluation of the risk of damage to the crop). The algorithm used to make matches is a summation of the product of answer values which gives a measure of compatibility between the answers for a new case and a stored record. The raw compatibility score (R_c) is calculated as a sum of the product of answer values, which measures a form of covariance with an assumed mean of zero, calculated as:

$$R_c = \sum_{i=1}^{n} Q_w . v_a . w_b$$

with Q_w as the question weight, v_a the value for the answer from the new case being considered and v_b the value for the answer for a stored record. The system then generates compatibility scores expressed as a percentage which compares the users response to the records within the system. Defuzzification of these results is left to the user, the most likely risk assessment being the top item of the list, but other advice with high or similar scores should also be considered. See Winder *et al.*, (1997) for further details of this approach.

The expert shell was used to translate the decision tree of Dewar & Carter (1984) into a fuzzy decision support system. The decision tree had 5 questions which are included in this system (Table 1). However, rather than a deterministic approach following a pre-determined route through the decision tree, the probability of decision outcome is determined by the system and represented by a probability expressed as a percentage. The probabilities do not reflect a direct comparison to a calculated threshold but rather reflect the 'impression' an expert would have when provided with the same information. Weightings and response values were selected to represent the relative importance of each component within the decision tree.

Table 1. Example of implementation of the fuzzy logic system for the decision tree of Dewar & Carter (1984) which assesses the risk of summer cereal aphid outbreaks. The five questions correspond to those in the original decision tree. Type of question, weights and possible response values are given and were chosen to reflect the relative importance of each element within the decision tree.

Question	Weight	Responses	Response values
1. When was crop sown ?	1	Before October 14	+1 if yes, 0 if no
		After October 14	"
2. How many alates were caught in suction traps up to 7 days after sowing date ?	2	Lots	+1 if yes, 0 if no
		A few	"
		None	"
		Don't know	"
3. How severe do you think the winter was ?	1	Very severe	+2
		Quite severe	0
		Quite mild	0
		Very mild	-2
4. How many alates have been recorded in your local RIS suction trap ?	5	A lot	+1 if yes, 0 if no
		A moderate number	"
		Hardly any	"
		Don't know	"
5. How many natural enemies are present this year ?	5	A large number	+5
		A moderate number	0
		Very few	-1

RESULTS

The decision support system was tested and three scenarios are given below (Table 2) which illustrate the advice given. The results from the decision support system may be interpreted by inspecting the probabilities of outcomes and, in particular, considering the range of probabilities generated. Hence, in scenario (i) where an aphid outbreak is likely, the system assigns a 100% likelihood of a 'very high risk of damage' outcome. The relatively large distance between this and the second possible outcome indicates that this single outcome is very likely. Conversely, in scenario (ii) the information input into the system results in a range of outcomes with very similar, and rather low, percentage likelihoods. This implies that the information provided is not sufficient to identify a likely outcome and that to make an informed decision about pest control further monitoring is required. Scenario (iii) is based on data reported in Dewar and Carter (1984), where there appeared to be a high risk of aphid damage but very high natural enemy numbers prevented this. The decision support given in this case is that there is a medium to low risk of aphid damage, but, given the similar probabilities of these outcomes further monitoring would be appropriate, albeit with the expectation that damage will not occur. The original decision tree assessed risk as moderate, and a peak density of *Sitobion avenae* of 2.5 aphids tiller^{-1} was reported by the authors.

Table 2. Standardised compatibility score listings for decision support system illustrating examples of results from three scenarios.

Scenario (i) - DAMAGE LIKELY. Early sowing, with high numbers of overwintering aphids, a mild winter, high spring migration and few natural enemies.

Output from system

100 VERY HIGH RISK
54-77 HIGH RISK
22-40 MEDIUM RISK
0 VERY LOW RISK

Scenario (ii) - POSSIBLE DAMAGE. Late sowing, high numbers of overwintering aphids, a severe winter, moderate spring immigration and a moderate number of natural enemies.

Output from system

62 MEDIUM RISK
56 VERY LOW RISK
56 HIGH RISK
50 VERY HIGH RISK
18 HIGH RISK (due to overwintering aphids)

Scenario (iii) - DAMAGE CONTROL BY NATURAL ENEMIES. Early sowing, a few overwintering aphids, a mild winter, high spring migration and a high number of natural enemies.

Output from system

94 MEDIUM RISK (but control likely due to natural enemies)
90 VERY LOW RISK
19 MEDIUM RISK (no control by natural enemies)
8 VERY HIGH RISK OF DAMAGE
4-5 HIGH RISK (due to effects of either spring migrants or overwintering aphids)

DISCUSSION

Forecasts vary in their relevance to the farmer. They are only useful if they deliver appropriate information to a grower at a time when it will aid a decision. Whilst we justify different monitoring and forecasting schemes in a mechanistic way - and assume that they are based on scientific calculations - the reality is that local knowledge is used to moderate the results of relatively inaccurate observations. In many circumstances, qualitative information can be more important than quantitative data; whether the field has a history of the problem may be more use than knowing how many individual pests there are.

The approach we present in this paper combines quantitative and qualitative information in ways that allow for uncertainty. Fuzzy logic is a technology that encompasses relativity within answers and, as such, enables interpretation of conclusions in a manner appropriate to on-farm implementation. It is particularly good at dealing with observational inaccuracies, especially the ones that make quantitative predictions difficult, and unknowns.

The fuzzy logic translation of the example decision tree answers one of the problems highlighted by Dewar and Carter (1984); they noted but were unable to account for a number of intermediate pathways within the boundaries of 'outbreak' and 'no outbreak' outcomes. It is this power to consider all possible outcomes that we argue needs to be deployed in expert systems. Although the presented case study is relatively simple, it could be refined further. For example, questions that involve the respondent in making qualitative judgements about numbers can be calibrated to the individual and weightings of response values moderated to reflect different local conditions.

The current basis for our decision making lies in a pseudo-quantitative model which is adjusted to suit perceptions of local conditions because the absolute nature of the outputs do not suit our needs. Increasing reliance on expert systems for crop protection decision support will not deliver either increased profits or environmental benefits if these systems do not reflect the uncertainties of the real world. Fuzzy logic is a technology that can deliver a clearer sense of that reality and more accurately reflect human thinking.

ACKNOWLEDGEMENTS

The 'Matcher' expert system is copyright of M. Lefley. Windows and Visual Basic are trademarks of the Microsoft Corporation.

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SESSION 6B

FOOD SAFETY AND PESTICIDE RESIDUES – IS THERE A PROBLEM?

Chairman & Session Organiser	S J Crossley *Pesticides Safety Directorate, York, UK*
Papers	6B - 1 to 6B - 4

Food safety and pesticide residues - a response by industry to customer needs

M C Neale, M Gut-Rella, X Ledru, P Newton
Novartis Crop Protection AG., CH-4002 Basel, Switzerland

ABSTRACT

For many years, the setting and understanding of limits or levels of pesticide residues permitted in food (Maximum Residue Limit – MRL) has given rise to much controversy, particularly due to the differing points of views of the consumer, the regulatory authorities, the food industry, farmers and the pesticide manufacturers.

The presence of residues on treated crops does not of itself present a risk to the consumer. In some cases the presence of residues, within the designated limits, is necessary in order to protect the crop from pest or disease attack. It is of course a mandatory requirement to produce documentation to ascertain the risks of any pesticide to the consumer. There is no dispute about the need to have effective and efficient systems to ensure food safety and quality; we must guard against potential health hazards while continuity of food production is assured.

In reality, safety does not mean "no residues". However, today's perception is just the opposite. There needs to be an understanding or "partnership" approach to this issue. This paper outlines a few examples of such approaches taken by industry.

INTRODUCTION

While the farmer is the direct customer of the crop protection industry, both the industry and farmers must work in partnership with the industry's indirect customers, government regulators and advisers, food processors, retailers and importers and, most importantly, the general public. However the picture is further complicated by import and export of foods across international boundaries where varying regulations are in force.

INTERNATIONAL MOVEMENT OF FOOD – THE NEED TO ESTABLISH ACCEPTABLE RESIDUE LEVELS

The concentrations of pesticide residues tolerated in food (Maximum Residue Limit – MRL) can vary between countries to such an extent that crops or produce may be rejected by an importing country as the residues of an active ingredient exceed those that country permits, while they are acceptable in the country of origin. Maintaining an awareness of the different MRLs for the same active ingredient in different crops and countries is an essential point for international trade today. Achieving international harmonisation of MRLs should be the goal.

Codex

On the international level, the Codex Alimentarius Commission (a joint meeting of the FAO and WHO) recommends acceptable residue levels (or MRLs) in or on a food, agricultural commodity or animal feed. This Codex MRL is defined as the maximum concentration of a pesticide residue resulting from the use of a pesticide according to good agricultural practice. International acceptance of Codex MRLs should ensure that there are no trade barriers concerning importation of foods treated with crop protectant products where good agricultural practice is followed. However, is this the case in reality?

National Country Registrations

When registering an active ingredient in a new country, the applicant must follow the existing legal requirements of the national authorities to obtain an MRL for each crop to which the product will be applied. Taking all factors into account, such as the toxicology of the active ingredient, processing of the food if relevant, and local human dietary intake, a national MRL is set for the active ingredient in each crop to which it is applied.

Within Novartis, active ingredients/products are developed and registered on a national basis and the local group company is responsible for ensuring that they comply with the legal requirements for registration in each country, as well as meeting sales targets set in the local marketing plan.

Europe

In the past, individual states set their own residue levels, which could vary widely and were often used as barrier to free trade. To eliminate these discrepancies, and to open the borders within the European Union "single market", placing all the member states on an equal footing, the European Commission has attempted to introduce harmonisation of pesticide residue limits.

To achieve this goal, several additional directives have to be established to conform with Directive 91/414/EEC, which governs authorisation for placing plant protection products on the market. However, the EU has almost no resources of its own to complete this task, and progress is extremely slow. Consequently the completion of this harmonisation will take many years, and there is no way in which a pesticide producer can be sure when it will receive an EU MRL for any of its active ingredients. While several EU MRL reviews are underway, financial constraints mean that the authorities may not have the necessary resources to complete them.

United States

In the USA, the Environmental Protection Agency (EPA), together with the Food and Drug Administration (FDA) are responsible for the determination of an MRL or tolerance, as they are known, under the US Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and the Federal Food, Drug and Cosmetic Act (FFDCA). The Food Quality Protection Act of 1996 (FQPA) amended the overall regulation of pesticide residues under these two Acts.

In addition to a Federal registration, there may be additional regulations imposed at state level, as is the case with California where a pesticide must receive both US EPA and State Department of Pesticide Regulations approval before it can be offered for sale, possessed or used in California.

For international trade, the US EPA is required to publish a notice of a request for public comments whenever a proposed tolerance differs from an established Codex MRL. This requirement is part of the harmonisation efforts between US EPA and Organisation of Economic Co-operation and Development (OECD) and the North American Free Trade Agreement (NAFTA) to develop programmes and co-ordinate policies for pesticide regulations.

It is possible to apply for import tolerances in the USA; in addition to an extensive database on residue studies conducted in the country of origin under GLP (Good Laboratory Practice), the full data required to satisfy the EPA for local tolerances is required.

THE NEEDS OF THE FOOD INDUSTRY

Food companies seek information not only on a pesticide's biological activity, but also details of the product's degradation curve, residue levels in crops and the import tolerances set in the major importing countries to which these crops may subsequently be exported.

Novartis has arranged for an independent consultant to establish which problems the food industry has had in the last 12 months — concerning lack of good agricultural practice, potential residue levels, lack of promotion of IPM, problems with biological control, illegal use of Crop Protectants, concerns over safety to farmers, safety to consumers and environmental aspects.

The survey results showed that failure to follow good agricultural practice and perception of residue levels were seen as the greatest problems.

The need to use pesticides to produce healthy food at affordable prices was recognised; however the use of pesticides has to be supported by a strong product stewardship program to ensure low residues and environmentally sound production. The Crop Protection Industry as a whole or as individual companies were expected to be able to help in reducing levels and to promote GAP and IPM.

NOVARTIS ACTIVITIES

Within the planning and marketing processes, companies must consider both their own requirements for the international movement of crops, and those of the customers and the consumer. How can such requirements be met? There are many approaches including:

- developing new products with low use rates and low residues.
- ensuring that stewardship/IPM policies are in place and used.

• ensuring that international and import tolerances are established and no trade barriers are in place.

Several examples of actions taken by Novartis are given below:

Development of new active ingredients with low use rates and low residues

During the past decades, many new active ingredients with significantly reduced use rates have been developed have been developed, as shown in Table 1.

Table 1. Historic review of certain Novartis insecticides

Insecticides	Example	Year of introduction	Use rate g a.i./ha
Organophosphate (OP)	Diazinon	1953	500 - 1500
Carbamate	Furathiocarb	1981	1000 - 3000
Pyrethroid	Tau-fluvalinate	1985	30 - 150
Biological	Abamectin	1985	5 - 30
IGR	Lufenuron	1990	10 - 200
New mode	Pymetrozine	1993	10 –300

Taking data from Codex/Novartis proposals, the following downward trends in MRLs can be seen (Figure 1):

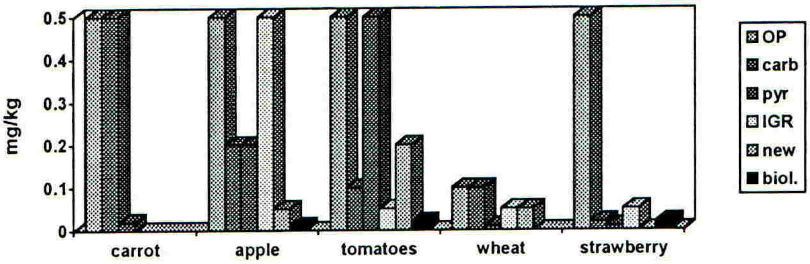

Figure 1. Downward trend in residues in crops (internal data).

Since modern insecticides tend to have higher acceptable daily intake rates than OPs and carbamates, one can expect that the theoretical chronic exposure is decreasing. In addition, modern insecticides are used more selectively. We have taken insecticides either developed by Novartis or in the Novartis portfolio and looked at the changes of use pattern and the subsequent theoretical chronic exposure (Figure 2).

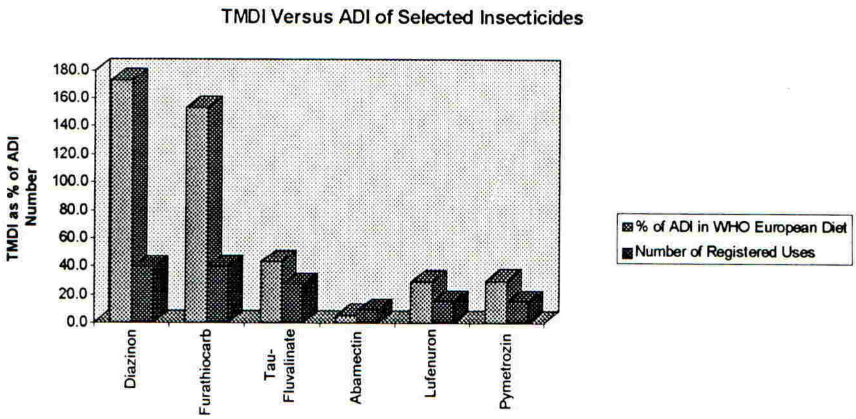

Figure 2. Changes in theoretical chronic exposure (internal data).

Crop management/protection programs

Novartis has rejuvenated its insecticide portfolio, with the objective of becoming the market leader in insecticides through:

- Satisfying customers needs with technically superior solutions.
- Effective and efficient concepts in Integrated Pest Management (IPM) and Insecticide Resistance Management (IRM).
- Innovation by introduction of products with new modes of action coming from our chemical and biotechnology research.

The type of change we are striving for is outlined in Table 2 and Figure 3. Our new portfolio includes products with 5 different modes of action instead of only 2; the total number of treatments is reduced from 9 to 6 applications per season requiring 6 times less active ingredient per hectare while the costs per hectare for our customer remain the same.

Table 2. Apple Programme (internal data).

PREVIOUS PORTFOLIO	NOVARTIS PORTFOLIO
4.5 kg a.i./ha	0.667 kg a.i. / ha
9 treatments	6 treatments
4 OPs out of 5 products	1 OP out of 5 products
No product can be applied during blossom	Tau-fluvalinate is harmless to bees
Dependent on one single a.i. family	IRM / IPM fit
197 Sfr. / ha	193 Sfr. / ha

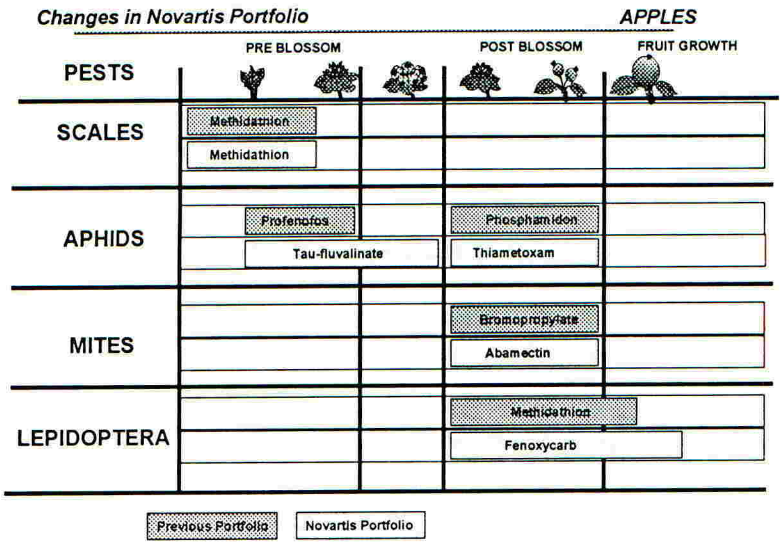

Figure 3. Changes in Novartis portfolio for treatment of apples (internal data).

Novartis IPM in Spain - Example of practical implementation of IPM

There are 23,000 hectares of plastic tunnels in Almeria, Spain, and it is a major production and exporting area for salad crops for northern Europe. This massive concentration of producers means there are no barriers to prevent the movement of pest populations, and the plastic tunnels are conducive to disease development. In this scenario it is perhaps no surprise that typical grower pesticide inputs are often based on 3-day calendar spraying of cocktails which contain at least two insecticides and two fungicides.

Trials began in the season 1992-93 to examine the potential for IPM systems and to define the necessary management techniques. Then in the 1993–94 and 1994–95 seasons, three tomato and pepper farms were selected for intensive monitoring. Detailed farm records of inputs and outputs in both IPM and grower plots were kept (see Figure 4).

Over two consecutive seasons, 1993–95, rationalised application of chemical products to both tomatoes and peppers led to dramatic reductions in quantities applied in IPM plots when compared to those under typical grower programmes. In the tomato crops, the average number of spray applications was reduced from 16.5 per season in typical growers plots to 9.7 in IPM plots, the number of insecticides was reduced from 15 to 9, and of fungicides from 13 to 9. The spray method was optimised with a saving of 11% water volume in the IPM plots, whilst the yield was maintained at 120 t/ha.

In peppers there was similar result with the average number of spray applications reduced from 14.4 per season in the grower plots to 11 in the IPM plots, the number of insecticides from 7 to 4 and of fungicides from 5 to 3. The spray method was optimised with a saving of 17% water volume in the IPM plots, whilst the yield and crop quality was marginally increased to 53 t/ha.

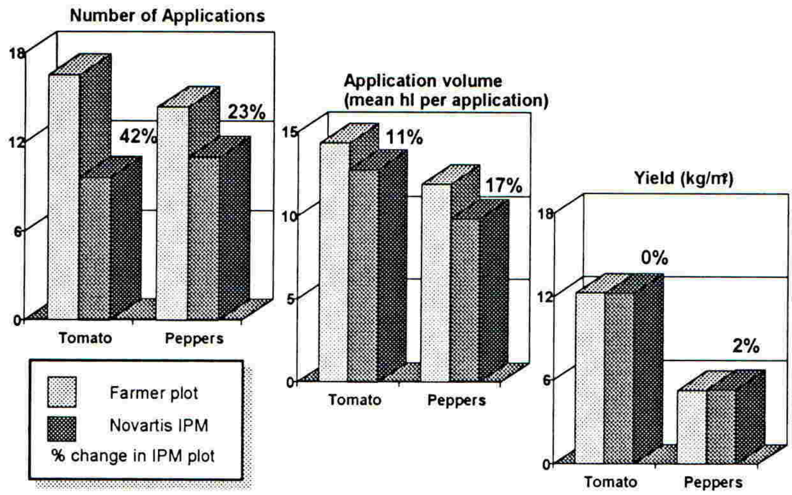

Figure 4. Average season-long effects over two consecutive seasons, 1993–95.

In addition, Novartis is working in the following areas:

- **Codex** - Submit all world-wide residue data and support international MRLs set by them to allow free trade.
- **Import Tolerances** - Apply for US Import Tolerances when commercially justified. Follow-up to establish EU MRLs, although such a system is not yet fully implemented.
- **Regulators** - Participate in the European MRL review for active ingredients. Continue to work with US EPA and European Commission and take part in dialogue on pesticide regulations to ensure decisions are science based.
- **Food Chain** - Understand the needs of the Food Chain. Establish projects in collaboration with the Food Chain to improve the quality of produce, to ensure worker safety and environmentally sound crop protection.
- **Public/Consumers** - Be open with scientific evaluations and provide reassurance.

CONCLUSIONS

The use of pesticides in the production of food crops is necessary in order to ensure consistent supplies of high quality food raw materials suitable for today's markets.

The Crop Protection Industry has a clear responsibility to meet its customers needs, be they the regulatory authorities, the farmers, the food chain or the consumers.

Through our commitment to develop new products to meet market needs, to replace older technologies, to establish new approaches for sustainable management of pests through co-operative and integrated programs, we believe we will be successful.

Food safety and pesticides residues: Is there a problem? A regulator's perspective

C A Harris
Pesticides Safety Directorate, Mallard House, Kings Pool, 3 Peasholme Green, York, YO1 7PX, UK

ABSTRACT

The regulatory assessment of pesticide safety and efficacy in the UK is carried out by the Pesticides Safety Directorate. It involves a multidisciplinary approach to consider all aspects of safety including consumers, operators and the environment. The assessment of consumer safety is carried out as part of a two sided process: hazard identification carried out by assessing toxicological studies and risk assessment carried out by estimating intakes by consumers. These are combined to ensure that adequate margins of safety exist for consumers who may be exposed to pesticide residues. The perception of risk by the consumer is commonly higher that that indicated by the science. Regulators must continue to make publicly available information on the risk assessment methodology and dietary intake models to ensure that consumers are fully informed of the procedures which have been designed to ensure their safety. The consumers can then make their own informed and educated judgement on the safety of the food they eat.

INTRODUCTION

The Pesticides Safety Directorate (PSD) is an Executive Agency of the Ministry of Agriculture, Fisheries and Food and is responsible for the approval and post-approval monitoring of pesticides within the UK. PSD consists of 11 branches covering both technical and policy issues.

The assessment of safety of pesticides is based on a multidisciplinary approach assessing the risks to consumers, operators, wildlife and the environment to ensure that the risks are identified, characterised and judged to be acceptable. Data are evaluated by specialists in areas of chemistry/consumer exposure, toxicology, operator exposure, ecotoxicology and fate and behaviour in the environment before being assessed by the independent Advisory Committee on Pesticides (ACP). If necessary, risk management measures may be specified and approvals for use will not be given unless the ACP considers a product is safe.

PROTECTING CONSUMERS

The expression of risk to consumers can be defined by the equation: *risk = hazard/exposure.*

Hazard and risk are terms which are commonly interchanged; in technical usage, hazard can be defined as the state of affairs that can lead to harm whereas risk is the probability of that particular event occurring in practice (Berry, 1994).

Hazard identification

The remit of toxicologists is to identify the hazard by evaluating data on metabolism and toxicity data on pesticides. The types of studies considered are shown in Table 1.

Table 1. Toxicology studies accessed as part of the hazard identification process in pesticide registration.

Type of study	Used to assess
pharmacokinetics and metabolism	absorption, distribution, metabolism and excretion of pesticides
acute single dose	effects of high dose exposure after gastrointestinal, skin or eye exposure
repeat dose (short-term to life-time)	effects ranging from behavioural changes to alterations at the biochemical level (e.g. enzyme and hormone changes) and macroscopic/microscopic level (e.g. cancers)
mutagenicity	effects on chromosomes and DNA
reproductive (teratogenicity/multi-generation)	effects on reproduction and offspring neurotoxicity effects on the nervous system
dermal absorption	the rate and amount of absorption of pesticides through skin
human surveillance data and biomonitoring	effects on operators or less frequently volunteers

From these data, an ADI for use in consumer risk assessment is derived. The ADI is defined as the amount of a chemical which can be consumed every day of an individuals' entire lifetime in the practical certainty, on the basis of all known facts, that no harm will result. The ADI is based on the no-observed (adverse) effect level in the most sensitive animal species or, if appropriate data are available, in humans. It invariably includes safety factors to account for both inter-species and intra-species variations in susceptibility. The extent of the toxicological database is probably only second to pharmaceuticals in terms of xenobiotics to which humans are exposed. Other chemicals found in food such as organic environmental contaminants or those found naturally usually have very little toxicological data supporting them.

The existence of susceptible groups of consumers, particularly infants and children, has also been the subject of debate particularly since the publication of the US study 'The Risk to Infants and Children from Pesticide Residues' (NRC, 1993). The report recommended that special attention should be given to these consumer groups because of their potential susceptibility to chemical residues. The International Life Science Institute (ILSI)-Europe workshop on the ADI and children recognised that the higher clearance in children would compensate (at least in part) for greater sensitivity of developing organ systems and concluded that 'special' safety factors for infants and children should not be used. Consequently, special ADIs need not be established. The toxicology database should adequately cover the most sensitive effects and the most sensitive age groups. If there is scientific evidence that infants and children are most sensitive to a particular contaminant, the evidence must drive the derivation of the ADI (ILSI, 1997). The debate on this point still continues.

PSD has also now developed methodologies which are capable of quantitatively assessing short term dietary risk from pesticide residues. These use a new toxicological measure similar to the ADI but relevant to a single meal or single day intakes, known as the acute reference dose (acute RfD). The acute RfD is based on toxicological studies relevant to short term exposure (Harris *et al.*, 1997).

Assessment of risk from long term dietary exposure

Consumer dietary exposure is a function of level of consumption and the level of pesticide residues present in foodstuffs. In 1997, the UK updated its modelling with respect to long term intakes by introducing the recommendations of the WHO (WHO, 1998). In effect, the theoretical maximum daily intake (TMDI), which is acknowledged as a gross overestimate of actual exposure, was replaced by the national estimated daily intake (NEDI). This would allow refinements (such as losses during routine processing) to be taken into account at the first stage of calculation. Like the TMDI, the NEDI is calculated using consumption data from dietary surveys for adults, school children and infants. Instead of using the maximum residue level or MRL (the highest level of residue likely to occur in or on treated produce as a result of the crop being treated according to the approved use often referred to as Good Agricultural Produce), the supervised trial median residue (STMR) is used. From monitoring data, it is consistently found that 70% of samples analysed do not contain detectable residues. Therefore, taking account of this and consumer eating patterns, it is considered that the STMR is a more accurate and realistic reflection of the residue level to which consumers may be exposed during their entire lifetime. The 97.5th percentile consumption level represents "high-level" consumption and is used as a "worst case". Food consumption data in the top 2.5% is considered to be less accurate due to the reliance on a very small number of consumers. These consumers are atypical and such eating patterns are unlikely to be maintained over a significant part of any individual's lifetime. The NEDI is expressed in terms of mg/kg bw/day (the same units as for the ADI) usually using average body weights although actual body weights are preferred and is calculated using the following equation:

$$NEDI = \frac{\text{97.5th percentile consumption (kg/day)} \times \text{STMR (mg/kg)} \times \text{corrective value of food commodity for increase/decrease in residue level}}{\text{body weight (kg)}}$$

In the UK, expert committees consider this "high-level" approach is satisfactory for pesticides that have chronic effects for which concern is about exposure over a lifetime. The intake estimates are based on measured consumption data collected for adults (16-64+ years old) (Gregory *et al.*, 1990), schoolchildren (10/11 and 14/15 years old) (HMSO, 1989) and infants (6-12 months) (Mills & Tyler, 1992). The NRC report again noted that it was necessary to take account of different eating patterns of infants and children. By using separate models, PSD ensures that the low body weight and limited diet of infants, the large consumption per body weight basis of school children and wide range of foods consumed by adults are taken into account. PSD is looking to expand its models to cover toddlers and vegetarians in the future as soon as consumption data become available.

The NEDI still represents an overestimate because of the assumptions made such as consumption throughout the entire lifetime will be maintained at the 97.5th percentile level. (Harris & Crossley, 1996; Crossley & Harris, 1996; WHO, 1995)

Assessment of risk from short-term dietary exposure

For fruit and vegetables, consumers have been concerned about acute exposure to residues where the residues in a single item exceed the MRL. One of the primary use of MRLs is a trading standard and they are based on bulked or composite samples rather than individual crop items. Sampling of bulked samples is carried out using an established process designed to ensure that the sample is representative. Recent work on carrots has indicated that the variability in residue levels between individual roots has been high (PSD, 1995). There is little firm evidence as to why this phenomenon occurs and research to address this phenomenon is ongoing. It is still recognised that sampling of bulked commodities offers the most appropriate means of ensuring that traded commodities do not contain unacceptable levels of pesticide residues. The Regulatory Authority is responsible for ensuring that any variation of residues within a bulked sample which conforms to the appropriate MRL does not give rise to an unacceptable risk to consumers when individual items are consumed. Adverse effects from acute exposure to the levels of pesticide residues routinely found are very unlikely to occur because it would be necessary to consume a large toxic dose of a pesticide in a single meal. For this to occur, a compound would need to:

(a) have high acute toxicity at a low dose; and
(b) be consumed in significant quantities in a single meal.

PSD now routinely estimates acute dietary intake and, where appropriate, an acute RfD is derived. Guidance on the methodology for assessing acute dietary exposure is being further developed and refined at PSD and also by the FAO/WHO. Consumer risk assessments now not only take account of short-term intakes and additional calculations of intakes by toddlers but also the variability of residues between individual units of some fruit and vegetables (PSD, 1997).

Monitoring of pesticide residues in food

Monitoring of pesticide residues in food is carried out under the auspices of the Working Party on Pesticide Residues (WPPR). Despite running programmes that seek different wide ranges of pesticide residues in varying wide ranges of foodstuffs, the overall findings are consistent from year to year. Generally, no residues are detected in 70% of samples, residues are detected in 29% of samples and residues exceeding MRLs are found in 1% of samples. The programme covers dietary staples (bread, potatoes and milk) each year with a range of other fruit and vegetables, products of animal and fish origin, and cereal and cereal products being monitored between 1 in 3 and 1 in 7 years. This frequency is based primarily on contribution to the diet, patterns of usage - both legal and illegal - and findings of other agencies carrying out such work. Analytes vary depending on the substrate being analysed but generally organochlorines are sought in products of animal and fish origin, and organophosphorus compounds in fruit, vegetables and cereals. Wide ranges of other insecticides and fungicides are also sought often over 100 in any one sample. The WPPR has already begun to extend its work programmes in a focused way to address other areas of concern. In recent years, many MRLs have been set for non-organochlorine residues in products of animal origin. These compounds have been included in the programme and will be sought in liver, kidney, chicken and beef in 1998 and lamb, pork and turkey in 1999. Depending on findings, further work may be carried out in meat-based products if significant levels of these residues are found. Although herbicides are the most frequently used pesticides (Anon. 1998), the WPPR have not extensively sought these residues since they are generally applied early in a crops' development and are usually assumed not to give rise to detectable residues. However, a two year programme in 1998-9 will assess this assumption.

Where unexpected residues or residues above MRLs are found, the WPPR assesses the risk to consumers. Even in the rare event of the ADI being exceeded such as dithiocarbamates in two samples of apricots in 1996 (MAFF, 1997), the ACP concluded that "given the low number of samples containing the residues and the frequency of occurrence of high level residues, exposure at this level would be unlikely to occur regularly and no adverse effects on health would be expected from occasional, minor exceedances of the ADI. The intake of the average consumer would be within the ADI."

The perception of risk

Consumer perception is more likely to follow the equation: *risk = hazard/ exposure × concern*

Often, the perception of the risk of pesticide residues by the consumer is much greater than the risk itself. In a study in the 1980s in the US (Upton, 1982: cited in Anon, 1998), three groups were asked to rank events which contributed to death – pesticides were ranked between 4 and 15 depending on the group surveyed. However, Upton's own research showed that pesticides actually rate at number 28 behind activities such as mountain climbing and cycling! Shaw (1996) compared the risks from naturally occurring toxicants such as psoralens in parsnips and solanine in potatoes as a result of not treating with tecnazene and concluded the risks to consumers in these situations were greatly in excess of those from pesticide residues. We know that the public perception of risk associated with chemicals is extremely important in determining the public's belief and responses to chemical hazards and as a result, risk-benefit communication is becoming more important (Shaw, 1996; Frewer, 1997). Lindsay (1997) challenged the current consumer perception of regulatory practices and went as far as to describe the protective health effects of pesticides. It is therefore clear that the need to provide clear guidance, advice and information to consumers, to allow them to make their own decisions on whether they consider a risk acceptable, is now more necessary than ever.

CONCLUSIONS

The assessment of risk to consumers from pesticide residues is a fundamental part of the UK pesticide approvals process. Unless consumer exposure occurs at levels toxicologically acceptable, a plant protection product will not be approved for use. In recent years consumer models have been developed in the UK where lifetime dietary intakes are calculated routinely for adults, children and infants and these will be extended to toddlers and vegetarians in the future. Acute dietary intakes are now routinely estimated and full acute risk assessments carried out for all compounds except those with no relevant acute toxicity. Apart from the single point estimates which are carried out at present, computer models capable of using Monte Carlo simulations to use a probabilistic approach to aid decision making in risk assessment are currently under development. Regular monitoring by the WPPR shows that residues are not detectable in most of our foodstuffs and even where the rare event of MRL exceedances occur, risks to consumers are considered acceptable. Data on risk perception indicate that pesticides are often ranked much higher than the relative risk in reality. However, consumers must continue to have access to the details of the risk assessment methodology and dietary intake models to ensure that they are fully informed of the procedures which have been designed to ensure their safety. The consumers can then make their own informed and educated judgement on the question "food safety and pesticide residues – is there a problem?"

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Food safety and pesticides – a retailer's view

R G Hilborn
Sainsbury's Supermarkets Limited, Stamford Street, London SE1 9LL, UK

ABSTRACT

Pesticide use and organic food production are considered from the retailer's point of view. The pesticide surveillance programme is discussed, as is work on Integrated Crop Management and organics that is considered in a pro-active position to reduce pesticide use and seek alternative crop protection measures. Finally, the important issue of customer communication is considered.

INTRODUCTION

World Agriculture is undergoing major changes. Clearly, it has always been changing but today more than ever customers are saying they want to know more. This is an interesting debate, there has been a major move of people away from the land. The countryside is not now seen as only a food-producing unit but also as a recreational place. This in itself brings pressures on land and how it is managed. There is a cost for this in increased management and knowledge of animal habitats and how they can be maintained and developed within the overall farm profitability. Post war farming has also been successful with no food rationing.

Many debates are taking place within Europe on agri-environmental policy, CAP reform and not least Agenda 2000. All need to be debated but more importantly if we are to fundamentally change agriculture, action taken.

Food safety must stand as the single most important aspect of our work to maintain consumer confidence. This has required a close relationship with suppliers developing improved standards at factory level but of equal importance at the source of food production, the farm. Believe it or not many aspects of these controls ultimately have an impact on the environment, also a key consumer concern. Whether it is pesticide reduction through Integrated Crop Management or pollution reduction by the correct use of fertilisers, which, hopefully and the evidence is building also brings a reduction in costs. The debate on pesticides use continues the UK retailers are addressing these in various ways on the farm and with customer information.

PESTICIDE USE

Although, there is no clear evidence that implicates pesticides in health concerns, we should acknowledge that customers are not placated by statements issued by regulatory authorities, manufacturers and even retailers regarding the safety in their use. Their key concern is pesticide use, like all other chemicals they cannot be seen by customers when applied to the product. Also, while the full effect of pesticides on the countryside is uncertain, it could be argued that pesticides have played a part in reducing the richness and variety of our wildlife and the quality of our rivers and streams. They also may interfere with some of the natural processes which have kept farming in harmony with nature such as their effects on beneficial insects requiring further use of chemicals to regain the balance. However, it is important to note that our own surveillance programmes show no major concerns on residues, from all sources of supply of Fresh Produce to Sainsbury's. However, we must remain vigilant.

Major retailers have developed Integrated Crop Management Systems (ICMS) to address some of these concerns. There are now crop production protocols for individual crops covering production and storage and full auditing commenced in November 1997 under the "Assured Produce Scheme". This scheme is the first of its kind with retailers joining together. Full auditing will enable all parts of the food chain to examine where progress is being made or otherwise but also giving credibility to the system and confidence to the customer. If we believe in transparency for the consumer this is essential. The basis of this programme is to use pesticides as a last resort. But recognising the role of pesticides to produce high quality food at a reasonable price. To quote Dennis Avery, Director for Global Food Issues, Hudson Institute "Without the higher yields already achieved on the world's farms, the world would already have expanded its cropland needs beyond the current 15 million square kilometres to at least 40 million square kilometres and perhaps a good deal more" (Avery, 1996).

There is therefore a dilemma: by creating a more extensive low input farming system this could impact more on our customers of the future reducing the range and maybe availability of today's foods and impacting on the environment.

Perhaps through ICMS we have this middle road, using the best technology to apply expensive inputs at the correct time, which in turn will reduce overall volumes of active ingredient applied. This must not be at the expense of food safety or food security. The Irish potato famine is just one notable event in a world where many crop failures have occurred due to climate and to further impact on this with reduced pesticides would present even greater problems to the world's rising population.

We are, therefore, bringing the various control mechanisms together to give a farming industry which will work on a continuous improvement strategy. But, also recognising alternatives maybe essential if new chemicals are not available. However, not all observers will see this as the only way forward indeed some see it as a soft option and not addressing the key issues surrounding pesticide use. Some see organics as the truly sustainable approach, concerns on issues like unit to unit variation found in recent pesticide surveys on carrots and comments on organophosphate pesticides may fuel this debate and alarm consumers.

ORGANICS

Sainsbury's is one of the largest UK retailers. We sell a wide range of organic foods more than 300 products. Demand for organic fresh produce is growing at up to 20% a year and demand outstrips supply. Importation accounts for 75% of Sainsbury's organic produce, the cost to the consumer is around 25% more than conventional produce. This only reflecting the extra cost of production to the grower with lower yields due to crop loss and major yield reductions a real possibility.

In a recent Sainsbury's survey customers were asking for more organic products and this has happened over the last two years since BSE. This was the dewpoint which created the demand for more so called "Natural Products". This raised awareness and a need to know more about production techniques and interestingly where products originate, even the farmer who produced it.

What does organics give the customers?

Organics gives the opportunity for customers to buy products to a prescribed system of production regulated by the (UK Register of Organic Food Standards). One of the world's organic competent authorities. This in my view demonstrates the importance to all farming sectors the need for independently audited production schemes to give transparency to those outside and ultimately the customer. Some commentators are severely critical of conventional production systems. Clearly, there is a high degree of ignorance of farming practices and the care that goes into production. But complacency has no place if we are to ensure the customer maintains confidence in conventional produce. We all need to ensure the adequate control and application of chemicals with only those chemicals being recommended that have been approved for particular crops. At Sainsbury's we watch through our surveillance programmes and technical visits to ensure that this is the case. Ultimately this will all be through independent audits.

However, organics, represents a small part of our production. But has given leads to conventional farming to embark on schemes like ICMS. At Sainsbury's we have a programme to develop the organic sector through a group called SOURCE (Sainsbury's Organic Resourcing Club), this is proving highly successful and further work is underway with IFOAM (International Federation of Organic Agricultural Movements), the International group for promoting organic production worldwide.

I do not see a right or wrong way of production but a joint learning process, which must be based on sound science. The backdrop is a rising world population to be fed for, environmental concerns and ensuring consumer safety at all times. But to quote Dennis Avery again "When we triple the yields on the best and safest farmland, we cut the soil erosion per ton of food by two thirds. A key environmental message and perhaps supporting the ICM programme for more efficient use of resources, which includes the best land.

PESTICIDE SURVEILLANCE PROGRAMME

The work on Integrated Crop Management and organics is a pro-active position to reduce pesticide use and seek alternative crop protection measures. However, most retailers also carry out their own surveillance programmes to identify areas of concern, this is supported by supplier tests. These data are used on follow-up visits to suppliers worldwide identifying application methods and the type of chemicals used. The visits by technologist also focus our attention to areas of potential problems which can be investigated in detail by future surveillance programmes. On this note, we must recognise that misuse of pesticides has been identified by surveillance programmes and should be a warning to us all on the need for vigilance, this mis-use can only fuel the debate on pesticide safety.

CUSTOMER COMMUNICATIONS

We started customer communication of some of these ideas through our leaflet "The Quiet Revolution" in 1995. An important part of the communication is to reduce customer expectations of blemish free products but not at any cost. Bruised fruit for storage is not acceptable. But at the same time highlighting the eating quality, also the concept of marketing more of the crop. Apples in the United Kingdom last year is a good example of this where crops were devastated by frost so we sold Class II fruit. Customers need to understand the impact of this. The Supermarket needs to understand how we can best support such problems. More recently we have published a leaflet called the "Living Landscape" this discusses pesticide use and the environment. In the UK the effect of pesticides on Biodiversity remains a key issue and one we are addressing through our Biodiversity Action Plan working with UK farmers to introduce conservation techniques on farms. The need for customer information that can be supported by Independent verification will be important as we move to the year 2000.

CONCLUSIONS

Customers will become more demanding and knowledgeable about their food. New pesticides may not be readily available, there may be new regulatory controls on pesticides and fertilisers, e.g. nitrates. If farmers can reduce input costs there will be real current and long term benefits, that will not only support safety and better environmental practices but also benefit business objectives. If we all work together it will form a powerful process for change, not withstanding the work needed at a higher level within the European Community and by governments worldwide. There is no doubt the correct use of pesticides has helped to give customers a better range of safe, wholesome products. Results of our own surveillance work supports the view that chemicals are being used appropriately. However, our guard must never be lowered and improved methods of application and control must be our goal.

Farming worldwide has never been asked to change more than today. That needs support and understanding. Greater education of children in school — tomorrow's customers. I never fail to be amazed at the action being taken by farmers on their own even in difficult times. This has been given a more focused awareness in recent times. I strongly believe if we are to have shared responsibilities for all these programmes farmers will need considerable support so customers can have confidence in the production systems with balanced debate and reporting. The need for all sides of the food chain consumers, farmers, retailers and researchers talking together. We must at all times ensure this confidence is not shattered. We must all ask ourselves are we doing enough?

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The importance of food safety issues from the public perspective. Public perception and the consumer's interest in pesticide residues

R Luijk[1]
Consumentenbond, P.O. box 1000, 2500 BA The Hague, the Netherlands

L Y Lefferts[1]
Consultant, 5280 Rockfish Valley Highway, Faber, VA 22938-4001, US

E Groth III[1]
Consumers Union, 101 Truman Avenue, Yonkers, NY 10703-1057, US

ABSTRACT

The public perception of risks associated with food and pesticides is examined, and current risk assessment procedures for chronic dietary exposure reviewed. Particular attention is paid to organophosphate (OP) pesticides and the risks of exposure to children. Finally, risk management and the Codex process is discussed in detail, from the consumer's perspective.

INTRODUCTION

Pesticides have once again become a matter of public concern, most recently because of their endocrine disrupting impact on wildlife and human health (Colborn *et al.*, 1996). Consumers' and environmental groups have put this issue on the agenda of policy makers (Allsop, 1997; Beekman, 1998). In 1997 Greenpeace started a campaign on this issue in the Netherlands. A television spot showed two baskets of fruit and vegetables with the underlying text "good" and "bad". A voice said "The difference between good and bad has become invisible. From the outside you can not see if toxic chemicals have been applied during production". The next shots show pictures of possible consequences of the presence of hormone disrupting pesticides in our diets such as an empty baby stroller or a woman with one breast and a scar of an amputated breast. These images imply that pesticide residues hidden in fruits and vegetables cause cancer and infertility, and appeal to the consumer's desire for a simple answer: no pesticide residues in my food, no poison in my body. The consumer wants natural, good looking apples, strawberries and Brussels sprouts on his plate without toxic pesticide residues.

This article is written to try to bridge the gap between the consuming public's perception of foods and pesticides—abetted by media presentations such as illustrated above—and the workings of Codex, which embrace a risk assessment, risk management, and risk communication approach. It is Consumers International's intent to represent the consumer viewpoint effectively within the risk analysis framework used by Codex, and this paper presents a basis for doing so.

[1] Representing: *Consumers International, 24 Highbury Crescent, London, N5 1RX, UK.*

CONSUMER PERCEPTIONS OF RISKS

Consumers perceive risks differently than experts do. Different does not mean wrong. It is not a question of misperception by either the consumer or the expert. In fact, risks have many attributes.

Scientists and regulators tend, for a variety of good reasons, to focus on measurable, quantifiable attributes of risks. Ordinary consumers tend, for equally good reasons, to focus less on the quantitative aspects of risks, and more on qualitative, value-laden attributes of risks, things like fairness and controllability, which the expert community tends to ignore (Groth, 1991). To express this in the jargon currently fashionable in Codex contexts, the expert tend to emphasize risk assessment, while most typical consumers, while not inattentive to risk assessment, are also quite concerned with "factors other than science" that should legitimately be weighed in risk management.

Paul Slovic, a leading scientist in the field of public perceptions of risks, has shown that the risk perception strongly depends upon whether a risk is involuntary; whether the risk is out of an individuals control; whether it is inequitably distributed; whether it has potential for catastrophic consequences; and other attributes (Slovic, 1987). The more the risk falls into these categories, the higher the perceived risk, and the more people want to see the risk reduced, including regulation. As Slovic himself says, while these public perceptions of risk may not exactly match experts' narrower, quantitative definitions, the public's perceptions are in fact quite rational; they are merely wider, more qualitative and complex than experts' perceptions of risks, and they incorporate legitimate value-laden considerations that are valid dimensions of risks (Slovic, 1990).

Based upon some recent evidence, citizens do know the difference between large risks and small ones, and understand the relative risks rather well, better than we have realized (Groth, 1998). Consumers can tell large risks from small ones, and do not appear excessively worried that foods in general are unsafe. But at the same time, consumers say they are more "concerned" about certain small risks than they are about some other, larger risks. While scientists and regulators are more concerned about how many people will be harmed by the potential risk of pesticide residues and food additives, consumers have no control over how much they are exposed to, the public expects and wants governement agencies to be concerned with these risks, even though they are small. On the other hand, when it comes to food-borne pathogens, fat intake and certain food related risks, consumers percieve that they can protect themselves, they feel responsible for their own safety, and therefore are less likely to demand that government protect them. Differences between the public's and the experts community's perceptions of how important various risks are, and perhaps how acceptable they are, need to be brought closer together, so that both food safety officials and the public can be confident that policies are in the public's best interests. Closing this perception gap is a logical priority for risk communication.

Consumers approach the risk communication process with the goal of ensuring that decision-makers pay adequate attention to their concerns about risk-often such things as whether the benefits justify accepting risks, or whether there is adequate information for consumers to make choices in the market place and to manage their own risks in the case in question. With respect to the presence of pesticide residues there is more than the health issues that makes consumers ask for a wider choice of products, i.e. issues relating to sustainable agriculture and sustainable consumption. The structure of the conventional food production and agriculture systems are closely linked and in our opinion to much more dependent upon chemically based pesticide control. Consumers International strongly supports the development of Integrated Pest Management as an alternative of the current agricultural system. Consumers must have the right and the opportunity to decide what should or should not be included in our food, whether this is based upon sound science or additional considerations; moral, ethical etc. including the precautionary pinciple.

Consumers International has prepared a conceptual framework that can be used to assess why and how "other factors" should be adressed in all phases of risk analysis of food safety issues -and at all levels of the process - international (Codex) decisions, decisions by national authorities, and decisions by consumers in the marketplace (Consumers International, 1998). In all cases, science is a necessary basis for decisions, but never a sufficient base in itself. Furthermore science is not value-free, and even analyses and decisions made by scientific bodies typically are based upon both scientific and non-scientific considerations. Consumers International believes that a policy on "other factors" in Codex decisions is urgently needed, to promote clarity and greater transparency of decisions. Other factors that are inescapably part of Codex decisions intended to protect the health of consumers include a variety of subjective value judgements and social choices in the application of risk analysis. Among the most important are how to treat scientific uncertainty, and perceptions as to which risks are "significant". Other factors include economic concerns, such as feasibility of risk-management options, and the benefits of the activity or substance that poses the risks. Ethical issues, such as the rights and responsibilities of all parties involved in the risk management process, also enter the picture.

CURRENT RISK ASSESSMENT PROCEDURES

The current risk assessment procedures for chronic dietary exposure applied within Codex Alimentarius are primarily based upon the concept of the Acceptable Daily Intake (ADI). The ADI is the estimated amount of a substance in food or water, expressed on a body weight basis, that can be ingested daily over a lifetime without causing appreciable health risk to the consumer. For every pesticide an ADI is established from the No Observed Adverse Effect level in animal studies by applying safety factors intended to account for differences between animals and people (interspecies variation) and differences among people (intraspecies variation). In the current risk assessment procedures used by Codex, it is assumed that consumers are adults, weighing 60 kg for non-Asians and 55 kg for Asians.

The dietary intake is calculated from food consumption data and pesticide residue data, for different food commodities. The GEMS/Food system contains estimates of the average daily per capita consumption for each food commodity within five regional diets, i.e. the Middle East, Far East, Latin America, African and European diet. The Theoretical Maximum Daily Intake (TMDI) calculations, which have been used by Codex as the primary method of exposure estimation at the international level until last year, assume that all commodities present in the daily diet contain pesticide residue levels at the Maximum Residue Limits (MRLs) based upon "Good Agricultural Practice" (GAP), or nationally authorized uses. The TMDI calculations are considered to overestimate intake since only a portion of a specific crop is treated with a pesticide, most treated crops contain residues well below the MRL at harvest, and these are usually further reduced during storage, processing and cooking. Furthermore, it is unlikely that every food for which a MRL is proposed will have been treated with the pesticide over the lifetime of the consumer. Therefore, within Codex TMDI is considered as a worst case scenario that can be used as a screening tool for priority setting purposes, but which needs further refinement to more accurately assess dietary exposure.

Recently, the exposure assessment has been refined by the introduction of the International Estimated Dietary Intake (IEDI) calculations. Instead of using MRLs, the so-called Supervised Trial Median Residue (STMR) levels are used, and correction factors for storage, processing and cooking are applied in the intake calculations. The IEDI is considered as a more realistic approach to assess real life dietary intake on an international level. However, the procedure of calculating an IEDI as well as a TMDI and comparing it with the ADI does not take into account the following aspects which may cause an underestimate of the true exposure and risk for (some) consumers:

1) Children receive greater exposures (on a mg/kg-bw basis) than do adults to pesticides in their diets. This greater exposure should be explicitly evaluated and compared with data and methodologies (e.g., using FAO Food Balance Sheets) that are currently used by Codex.

2) Infants and children consume widely varying quantities of individual foods. To guard against excessive acute exposures, it is necessary to either use conservative assumptions or an additional uncertainty factor in the exposure estimation, or, where data are available, to develop distributions of exposure based on varying levels of residues and food consumption. MRLs should be set to protect highly exposed children, or at least 99% of children, based on the distribution of exposure.

3) Multiple pesticide residues routinely occur in the diets of infants and children, and some of these (e.g. organophosphate pesticides) share a common mechanism of toxicity. Therefore, pesticides with a common mechanism of toxicity should be evaluated together, with total exposure compared to a single ADI or reference dose.

4) Infants, children, and fetuses are more vulnerable than adults to many toxic effects of pesticides. In the absence of reliable data, such as when there are no pesticide-specific tests on immature animals for effects on the developing brain, endocrine and immune systems, children should be protected by an additional safety factor.

5) People, particularly children, may receive significant non-dietary, non-occupational exposures to pesticides. These non-dietary exposures should be explicitly considered in conducting exposure assessments.

6) Pesticides frequently pose both acute and chronic risks to infants, children, and fetuses. Both types of risks must be taken into account before MRLs are established.

ORGANOPHOSPHATE (OP) PESTICIDES OF PARTICULAR CONCERN TO CONSUMERS: CHILDREN AT RISK

At the 30th Meeting of the Codex Alimentarius Committe on Pesticides Residues Consumers International opposed the advancement of pesticide MRLs within Codex Alimentarius towards approval as international standards for an important and particularly worrisome class of pesticides, the organophosphate (OP) insecticides. This group of pesticides is of concern for consumer's health, especially for children, because the organophosphosphate pesticides are toxic to the nervous system. The developing brain is exquisitely sensitive to toxic agents such as OPs. Children receive relatively greater exposures to OPs in their diet than adults do. The concern is that this continued long term exposure could affect normal brain development, and subsequently, learning and behaviour. Children also recieve non-dietary exposures, such as through pesticides applied at home, on pets, or in school. Since all OPs share a common mechanism of toxicity, their toxic effect add up. Yet currently, Codex procedures pretend that consumers are exposed to one pesticide in the diet at a time, don't consider non-dietary exposures, and are directed towards adults, not children.

The US National Research Council concluded in its report 'Pesticides in the Diets of Infants and Children' (United States National Research Council, 1993):

> "The data strongly suggest that exposure to neurotoxic compounds at levels believed to be safe for adults could result in permanent loss of brain function if it occurred during the prenatal or early childhood period of brain development. This information is particularly relevant to dietary exposure to pesticides, since policies that established safe levels of exposure to neurotoxic pesticides for adults could not be assumed to adequately protect a child less than four years of age." (p. 61)

Following this report, the U.S. passed a new law, the Food Quality Protection Act of 1996, which requires (among other things) that the US EPA set tolerances that protect infants and children, and that the US EPA set tolerances for cumulative exposure to pesticides with a common mechanism of toxicity. EPA is currently moving ahead with implementation, a process bound to markedly change most OP and carbamate tolerances within the next few years.

A recent report by the Environmental Working Group entitled "Overexposed: Organophosphate Insecticides in Children's Food" (Wiles *et al.*, 1998) also documents the concern. The report is based on more than 80,000 US government lab test results from recent years and detailed data on children's food consumption. It found that every day, nine out of ten American children between ages 6 months and 5 years are exposed to combinations of 13 different organophosphate insecticides in the foods they eat. The report estimate that more than one million children in the US age 5 and under (1 out of 20) are exposed above the US EPA's ADI, and one hundred thousand of these children exceed the US EPA ADI by a factor of 10 or more. Generally, US EPA ADIs (called reference doses) are set similarly to ADIs used by Codex. The Environmental Working Group conclusions are based on the most sophisticated Monte Carlo cumulative exposure assessment ever completed for organophosphate insecticides.

Consumers International recommends that CCPR directs JMPR to study the EWG method and develop an adjusted ADI approach to sum up the exposure to different OPs and their potency to inhibit acetylcholinesterase similar to as has been developed by the JMPR for dithiocarbamates with a common mechanism of toxicity. Besides these chronic intake concerns CI supports the development of methods to assess the acute dietary intake of OPs which adress to the large unit-to-unit variation and the large portion size intake.

RISK MANAGEMENT AND THE CODEX PROCESS: A CONSUMER PERSPECTIVE

Many consumer organizations have difficulty in accepting the current approach used by Codex and numerous countries to assess and manage the risk from pesticides, for the following reasons (Lefferts & Groth, 1997):

1. **The risk management decision-making process does not assess alternatives to pesticide use.**

   Implicit in the risk management process is the judgement that pesticides are indispensable to agricultural production, public health and consumers' quality of life. The most promising way to achieve reduction in the dietary intake of pesticides and to protect public health is to change the intensively chemical-dependant approach to pest management. An alternative approach called biolocially-intensive Integrated Pest Management (IPM), which relies primarily on biological and ecological interventions such as pests' natural enemies, offers a sounder and safer pest control. (Benbrook *et al.*, 1996)

   Nowadays, consumers tend to ask more and more for organic food products. The share of organic production in several European countries is increasing. Austria, Denmark and the Nordic countries lead the field. For instance, the share of organic dairy-produce in Denmark is 12%. In the Netherlands the environmental movement organized a campaign in 1996 entitled "A belly full with poison" where strong recommendations were given to reduce the dependancy on chemical pest control methods, in other words how to get off this pesticide treadmill by introducing and stimulating safer, ecologically sounder and more cost-effective IPM methods (Muilerman & Steekelenburg, 1996).

   Codex documents assert that GAP "takes into account the minimum quantities necessarry to achieve adequate control, applied in such a manner that the amount of residue is the smallest practicable, and which is toxicologically acceptable," but this is widely considered to be untrue. For example, in the US, efficacy data are not required as part of the registration of a pesticide, and there is no assurance that the minimum quantity is used. In fact, many farmers around the world use much smaller quantities of a pesticide than is dictated by GAP and still achieve adequate control; other farmers under comparable conditions achieve adequate control without any use of the pesticide.

2. **The full impact of pesticides on human health is not known.**

   Consumers generally do not accept absence of proof of harm as a proof of safety, particularly when standards fail to consider adequately the need to protect sensitive subpopulations (e.g. children, infants, nutritionally comprised people, elderly people, people taking immune-suppressing medicines). More attention should be paid in the standard toxicty tests to new insights in neurotoxicity and toxicity to the developing immune and reproductive systems. Multiple exposure pathways should be adressed in the establishment of standards intended to protect public health (e.g. through diet, drinking water, air, exposure from indoor treatments, lawn and garden applications, golf courses, etc.). Finally, concurrent exposure to other toxic substances with the same mechanisms of action may influence the impact of pesticide residues. Especially the OPs are of concern. As a first step the common mechanism of toxicity of EBDCs has been adressed in the 1997 CCPR Meeting. At this meeting CI proposed that JMPR was asked to evaluate a similar method for OPs as well.

3. **Pesticide risk assessments attempt to define a "safe" or "acceptable" level of exposure, using science-based conventions.**

   The criteria experts use to define "safe" exposure ignore factors weighed by ordinary citizens in their definition of "acceptable", such as whether exposure is known, voluntary, or controllable by the consumer. Consumers, who seldom can tell which pesticide residues are present in foods they buy and limited in the choices they can make to avoid these risks, often do not equate the experts' definition of "safe" with "acceptable risk". Consequently, consumers regard risk assessment skeptically as a tool that hides major social value choices in a mantle of "scientific decision-making".

4. **Developing the data and risk assessments needed to manage pesticide risks is expensive.**

   Understanding and managing pesticide risks costs more than $17 billion from 1971 through 1995, about 7.4 per cent of gross pesticide sales in the US (Benbrook *et al.*, 1996).

   The central challenge is shifting government and international programs from an emphasis on regulating the use of and the resulting pollution from agricultural chemicals, to reducing pesticide problems by finding safer, effective pest control methods.

CONCLUSIONS AND RECOMMENDATIONS

With regard to the question whether there is a problem with food safety and pesticide residues, the answer from a consumer perspective is clearly yes. In the consumer perception the presence of pesticides falls into a category of involuntarily, incontrollable and unnecessarily exposure to toxic chemicals that are specifically designed to kill, and may pose a health hazard to humans too. Therefore, the public expects and wants governmental agencies to be concerned with these risks, even though they are small. Consumers are quite capable in ranking the risk of food safety issues and risk issues in general on a qualitative basis. Consumers want to participate in the international established risk analysis procedures. The main (general) goals of Consumers' International in Codex are:

- a more honest and respectful two-way risk communication;
- transparancy of the full process of risk analysis;
- full consumer participation in this process;
- protection for all consumers (including children).

Good Agricultural Practice upon which MRLs are based should be changed forward into Integrated Pest Management, where pesticides are the last defense. Our goal is to minimise the use of pesticides and to reduce the human exposure to pesticides – unnecessary exposure to even "safe levels" of pesticides should be prevented.

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