SESSION 1

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ENVIRONMENTAL IMPACT : PUTTING PESTICIDES INTO PERSPECTIVE.

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ABSTRACT

Environmental effects of pesticides are considered in relation to the need to maintain the highest standards of environmental protection and in the context of other agricultural activities and impacts on the environment. With current safeguards, hazards from pesticides are modest against this perspective. However some aspects of behaviour in the environment are not yet fully understood, for example behaviour in the lower soil/groundwater. In considering future developments, the problems of assessing ecological effects are discussed and pragmatic approaches described. The need for further reductions in the burden on the environment through improved methods of application and formulation and advances in integrated control is stressed. The potential for earlier, more deliberate consideration of environmental properties in pesticide development is considered. While there is thus scope for further progress on several fronts, the existing stepwise approach to environmental assessment appears to work well.

INTRODUCTION

Environmental aspects of agrochemicals have for so long been the focus of technical debate and strong emotion that it has become difficult to view the subject dispassionately. However, with the current upsurge in environmental awareness among the general public and politicians, there is renewed interest in traditional concerns. It is therefore timely to re-examine the environmental considerations which apply to pesticides and to assess how far existing achievements meet current expectations. The discussion which follows embraces all categories of pesticde, but with particular emphasis on weed control and herbicides, which are the subject of this Conference.

It should be emphasised at the outset that it is in the interests of all to safeguard the environment. This must be the philosophy of those involved in the production and use of pesticides and is indeed widely accepted. Thus, much attention and substantial resources are devoted to environmental matters during pesticide development.

In considering directions for the future, it is important to identify developments which could genuinely contribute to further improvements in the quality of life or protection of the environment. In a world with many unsatisfied needs, misguided pursuit of illusory environmental goals is just as reprehensible as any other profligate waste of resources. On the other hand some real problems remain to be resolved. The balance between benefits and risks can be difficult to strike and may differ with location and change with time.

THE ISSUES

In any re-examination of objectives and courses of action, it is helpful to go back to first principles and recall the underlying issues. In the case of environmental aspects of herbicides, these may be stated in the following way. Herbicides have become an established part of modern farming practice, providing a highly efficient, cost-effective, flexible and convenient method of weed control. This has contributed to substantial increases in yield, productivity and consistency of production and to eliminating the drudgery of the tedious and demanding manual task of hand weeding. However the properties of herbicides and their method of application create the possibility that they may affect unintended recipients and have indirect effects. This is because they cannot be completely selective or confined to the intended target and must in most cases have at least a degree of persistence. They may move from the intended area during application (by drift) and after application (by run off, leaching, vapour transfer and wind erosion). As a result they have the potential to contaminate water and food, either directly of via food chains. Similar arguments apply to other types of pesticide. There is an absolute obligation on those involved in the development and use of pesticides therefore to ensure that amounts applied do not exceed levels which the environment can accept without harm. These levels will be determined by the capacity of the environment to disperse, degrade and inactivate the compound and by the environmental sensitivity (susceptibility of key species, uniqueness, ecological robustness). This obligation has long been appreciated and is an established integral part of pesticide development.
It must also be recognised that public aspirations are increasingly going beyond this basic obligation. The underlying view is that the extended presence of anthropogenic material in the environment should be avoided, even if this is of no known toxicological significance. This view must be acknowledged however "logical" or otherwise it is perceived to be by the expert. Equally, it is to be hoped that those holding this view acknowledge the benefits which the careful use of pesticides can bring.

SOME INITIAL PERSPECTIVES

For a balanced view, the application of pesticides should be seen in the wider context of anthropogenic impacts on the environment in general. Further, in assessing these impacts it should be recognised that the environment can tolerate certain impacts without impairment.

The Agricultural Environment

The establishment and practice of agriculture, even "traditional" agriculture and organic farming, can have a profound environmental impact, generally more severe than any effects of using pesticides. The following brief examples provide illustration.

- Clearance The traditional farming landscape of Europe and North America, so admired by conservationists, was mainly produced by drastic forest clearance and drainage which virtually destroyed the existing ecosystem. For example, the whole central basin of South-East England, now occupied mainly by mixed farming, was filled by the great oak forest of Andredsweald until the middle ages (Whitney, 1976). Contemporary clearance of tropical rainforest causes much public concern.
- Cropping patterns Changes in cropping policy, often determined by fiscal incentives, self-evidently have environmental consequences. Some are obvious and visual such as the rapid proliferation of oil-seed rape in Europe in recent years. Others may be less visible but equally significant. Soil structure is markedly affected by a change from permanent grassland to arable crops. For example Table 1 shows results obtained in classical work by Low (1972) on soil aggregate stability under different systems.

Table 1.

Aggregate stability of silt soils in Lincolnshire (Low, 1972).

	Aggregate stability*	Organic carbon,%	Total nitrogen,%
Old grassland	82.2	3.79	0.39
Old arable	0.3	1.08	0.10

* Expressed as percentage of oven-dry soil particles of diameter <0.5 mm in water stable aggregates of diameter >0.5mm.

Even apparently minor changes can disturb ecological relationships. This is well demonstrated by the effects of cereal varieties on pathogen populations, illustrated in Table 2 by the changes in yellow rust (Puccinia striiformis) races on wheat which caused breakdown of host plant resistance as different initially resistant varieties were introduced sequentially in an attempt to maintain control (Johnson, 1987).

Table 2

Changes in races of *Puccinia striiformis* collected in the UK in response to introduction of new varieties (taken from a more extensive list given by Johnson, 1987).

Year	Race	Wheat varieties
1952	40E8	Nord Desprez
1955	32E160	Heines VII
1966	37E132	Rothwell Perdix
1969	104E137	Maris Beacon, Maris Nimrod
	108E9	Maris Ranger
1971	104E137 Type 2	Joss Cambier
	41E136 Type 2	
1981	108E141 Type 3	Brigand, Gawain
	108E9 Type 2	Moulin, Hobbit
	106E139	Hotspur
	109E141	Norman, Brimstone

Furthermore, changing varieties may have adverse effects on certain wildlife which use crops as a partial food source (Tapper, 1988)

- Mechanical Operations Particularly when heavy, powered machinery is used, mechanical operations would be expected to have effects on soil physical properties, although in practice problems are few when machinery is used properly. What is less widely appreciated is that mechanical operations can have clear effects on, for example, soil microbial populations. Somerville (1987) reports that populations of natural micro-habitants in soil can be depressed by up to 90% by ploughing, harrowing and other mechanical treatments.
- Soil Fertility Any major adverse environmental effects from modern farming practices, including the use of herbicides, would be expected to become manifest through declining agricultural yields or soil fertility. Occasional adverse effects from herbicides, mainly due to accidental misapplication, have been reported. However, specific investigations into the long-term effects of repeated applications of herbicides, such as those at the Weed Research Organisation (1983) have been reassuring. No adverse effects on yields were observed in long-term field experiments in which crops of wheat, barley, maize and carrots were grown on plots where tri-allate, MCPA, simazine or linuron were applied for some 20 years.

Toxicological Perspectives

Selective toxicity has been the touchstone of modern herbicide development. In relation to their intended function of weed control, this has involved varying degrees of selectivity between plant species to give the range appropriate for different applications. The levels of such selectivity which can now be attained are remarkable. From the environmental standpoint the selectivity in favour of other classes of organism is more often the focus of attention. In this connection, a key feature of most modern herbicides is that they attack processes (notably photosynthesis) which operate only in plants. There is thus no a priori reason why they should be particularly toxic to other classes of organism. Experience confirms this expectation. For example the majority of herbicides introduced commercially over the last 20 years have LD 50 values for acute toxicity of the active ingredient to rats exceeding 2000 mg/kg, which is less toxic than aspirin or caffeine (Table 3). It should be acknowledged that the toxicity of the active ingredient may be modified favourably or unfavourably by additives and carriers employed in formulating products.

Table 3

Toxicity of representative herbicides to mammals.

Herbicide	LD50 to rats mg/kg
Alachor	1200
Asulam	> 5000
Chlortoluron	> 10000
Cyanazine	1200
Flamprop-isopropyl	> 3000
Imazapyr	> 5000
Glyphosate	4320
Metribuzin	2200
Sulfometuron-methyl	> 5000
Terbacil	5000
Terbutryne	2380
Aspirin	1750
Cafeine	200

Equally the carcinogenic potential of pesticides is often much less than many materials (including natural substances) to which the population is routinely exposed. This subject has been addressed by Ames et al (1987) who calculated an index of hazard (HERP, expressed in per cent) defined as the human exposure dose/rodent potency dose. Human exposure figures were the daily lifetime doses as a result of representative food and water consumption, breathing ambient air etc. Rodent potency was estimated as the daily dose rate which would halve the per cent of tumour-free animals by the end of a standard lifetime.

Table 4

Relative Carcinogenic hazards (from Ames et al, 1987)

Substances	Carcinogen	Possible hazard (HERP*) (%)
Tap water	Chloroform	0.001
Conventional home air	Formaldehyde Benzene	0.6 0.004
Peanut butter (one sandwich)	Aflatoxin	0.03
Mushroom (One raw)	Hydrazines, etc.	0.1
Beer (12 oz)	Ethyl alcohol	2.8
Phenobarbital (One sleeping pill)	Phenobarbital	16
DDT/DDE (Daily dietary intake)	DDE	0.0003
EDB (Daily dietary intake)	Ethylene dibromide	0.0004

* HERP is defined as Human exposure dose/Rodent potency dose.

Relative Burdens on the Environment

The application of pesticides differs from many other routes by which anthropogenic chemicals enter the environment. Firstly having beneficial effects, it is deliberate and correspondingly can be subject to greater control through the selection and extensive testing of the products concerned and through methods of formulation and application. Secondly it is dispersed and at low area density (except in the case of accidental spillage). Environmental considerations are therefore different from those applying to more localised, concentrated discharges. Although strict comparison is clearly not valid, it is of some interest to consider pesticide application alongside other widely dispersed anthropogenic inputs to the environment. For example, in the case of acid deposition, it is estimated that global man made emissions of sulphur (mainly sulphur dioxide) amount to some 75 million tonnes annually, virtually all of which is deposited again, either unconverted or after oxidation. Organic urban waste in the USA alone amounts to approximately 150 million tons (Pimentel et al, 1980). In terms of the burden on the degradative and assimilating capacity of the environment, this may be compared with a total global pesticide production which has been variously reported as between 2 and 5 million tons over recent years. A trend towards increased usage has been offset by a substantial reduction in typical rates of application.

The purpose of these examples is not to try to discredit popular concern or to deflect attention from pesticides by pointing elsewhere. It is to give some reassurance and some measure of the scale and nature of potential hazards. Current understanding of the environmental fate and effects of pesticides and the status of existing safeguards will now be reviewed against this general background.

ENVIRONMENTAL IMPACTS

Perceptions of "the environment" can be rather vague, making it difficult to reach objective conclusions about observed or potential effects. For a systematic assessment, it is first necessary to have a clear concept of how pesticides may interact with the environment and some standard by which a potential or actual impact may be judged. For this purpose, environmental effects may be classified as follows:

- Direct harm to individual species, particularly those for which any adverse effect is unacceptable. Most obvious is man, but livestock, domestic animals and certain wildlife also feature prominently in this category.
- Effects on environmental function for example decomposition and recycling of natural and synthetic substances, providing a medium for crop and animal production, maintenance of habitat for man and other species.
- Effects on environmental resources, including biological resources such as genetic material.
- Effects on aesthetic or amenity aspects of the environment.

Although not explicitly constructed on this basis, the procedures which have evolved for assessing the environmental hazards of pesticides cover many aspects of this classification. Whereas initially they involved consideration of only acute toxicity to selected species, their cornerstones are now tests of direct toxicity to a wide range of organisms, tests of effect on key environmental functions and extensive investigations into the degradation and movement of the chemical in the environment (Table 5).

Table 5

Typical laboratory and small plot tests for environmental acceptability required by authorities. (Graham-Bryce, 1988a)

1950s	1980s
Acute toxicity: birds	Acute toxicity to fish (3spp).
Acute toxicity: fish	Fish, early life stage tests.
Acute toxicity: bees	Fish, bioaccumulation.
	Acute toxicity to aquatic invertebrates (4 spp).
	Acute toxicity to algae.
	Daphnia, reproduction study.
	Acute toxicity to bees.
	Acute toxicity to birds (2 spp).
	Dietary toxicity to birds.
	Effects on soil fauna.
	Residues in earthworms.
	Leaf litter decomposition.
	Effects on nitrification and CO_2 evolution from soil.
	Biodegradation rate, inhibition.
	Physicochemical properties, notably partition coefficient.

With respect to tests for effects on environmental function and resources, however, it may be questioned how far they assess ecological relationships which are also relevant. Some ecological considerations are, of course, addressed in current evaluation protocols, but the extent to which this should be extended is a matter of active debate. This is of considerable importance because the possibilities for study and hence the potential costs and resource requirements are almost limitless. Equally, it is particularly difficult to determine what constitutes a significant effect in this field.
The components of evaluation procedures for pesticides are considered more fully below in the light of these various considerations.

DIRECT TOXICITY

The determination of intrinsic toxicity in a laboratory test must continue to be the starting point for assessing environmental effects because this clearly reveal cases of severe risk and those where there is no significant potential hazard. Methodology for determining direct acute lethality is mostly well established and accepted. It includes techniques such as topical application, feeding tests, exposure to treated solution etc. which give relatively straight forward, unambiguous results. More sensitive indicators, such as tests for effects on reproduction (e.g with *Daphnia*) or on growth (e.g. the fish growth test developed by Crossland (1988)), are also now available. Considerable efforts are being made to replace animal tests by indirect methods wherever possible.

However, effects on some organisms are still difficult to assess. For example, despite extensive investigations into the effects of pesticides on the composition and activity of soil microbial populations, it is still difficult to draw confident conclusions because of soil variability and lack of reproducibility (Greaves, 1987). It seems unlikely that these problems can be overcome and thus pragmatic approaches must be adopted. For example, authorities in West Germany have adopted a series of defined criteria whereby further tests may be specified on the basis of the duration and magnitude of effects on soil respiration or nitrification activity in initial investigations. In other countries (e.g. USA and the Netherlands) authorities have withdrawn requirements for information on soil microflora, except for data on soil nitrification for soil incorporated chemicals. Greaves (1987) suggested another approach: a multiple toxicity test involving large numbers of pure cultures of microorganisms isolated from soil. This would amount to a collection of single species tests which could serve as a first tier evaluation which could preclude the need for expensive further testing for chemicals showing no inherent activity. More generally the sequential tiered approach to testing environmental effects can be strongly recommended. More detailed, complicated and expensive tests need only be undertaken if initial tests indicate that this is justified.

Experience with the very large number of compounds which have now been tested has shown that intrinsic activity can vary very widely between different organisms so that large degrees of selectivity can be obtained between target and non-target organisms. The selectivity achievable between different plant species which is the basis for many successful herbicide applications is a remarkable example. Understanding of the basis for selective toxicity (which depends on differences in metabolism, susceptibility at the site of action or penetration to the site of action in different species) is progressively improving as a result of biochemical, physiological and toxicological investigations. The long-term prospect which this opens up is that selective pesticides will eventually be obtained by molecular design based on structure/activity relationships and computer-aided modelling, rather than by high through-put screening and selection (Graham-Bryce, 1987).

EFFECTS ON FUNCTION

Because of the circumstances in which pesticides (especially herbicides) are applied, the environmental functions most likely to be affected are those in soil. Soil functions have correspondingly received most attention in evaluation procedures, particularly processes relating to soil fertility and to the degradation and cycling of materials. For example leaf litter degradation tests, which assess the vital function of the soil in recycling organic debris, have advantages of simplicity and ease of interpretation over species structural analysis in assessing effects on soil arthropods. Similarly, as pointed out above, tests on respiration and nitrification have been adopted to assess effects on soil microorganisms because of the difficulties in determining effects on population size. Such approaches deserve support because they address in

a straight-forward manner one of the principal areas of environmental concern identified above.
Many effects on agriculturally important functions will be expressed in the integrating properties of yield and ultimately soil fertility. Obviously pesticide use should enhance yield by controlling damaging organisms, but the overall advantage may result from this beneficial effect outweighing some minor negative effect on crop growth.

With respect to soil fertility, trials in which plots were treated annually with pesticides over a long-term period, such as those at the Weed Research Organisation (1983) and Rothamsted Experimental Station (Briggs, 1975) have been reassuring, as indicated above.

FATE OF PESTICIDES IN THE ENVIRONMENT

The assessment of toxic effects as discussed above, either direct or via investigation of function, is one pillar of modern environmental assessment. The value of this information is strongly reinforced by the other pillar - investigation of the behaviour of the substance in the environment. This statement is an expression of the central principle of ecotoxicology, namely that hazard is a function of both intrinsic susceptibility and the exposure experienced by receiving species. Exposure is determined by the bioavailable concentration and the time period over which this is experienced. The bioavailable concentration is in turn governed by processes such as degradation, dispersion, partition and sorption which attenuate the dose initially introduced into the environment.
Procedures for studying these processes are well established and involve laboratory and small plot experiments, together with extensive residue determinations during the development and commercial stages of new and established products. From such experience, together with basic research into environmental processes, much has been done to establish the underlying physico-chemical processes and relationships. It is increasingly possible to predict behaviour, using computer models and quantitative structure/activity relationships (QSARs), particularly when supplemented by comparison with established "benchmark" chemicals, whose behaviour in the environment is already well known. Table 6 gives one example: a comparison of measured and calculated physico-chemical properties for representative insecticides (Graham-Bryce, 1984). In view of the importance of environmental behaviour, such results greatly strengthen the case for including these approaches much earlier in the synthesis and selection processes for new pesticides.

Table 6

Comparison of measured and calculated properties for representative soil-applied pesticides (Graham-Bryce, 1984).

	Ethylene dibromide		Disulfoton	
	measured	calculated	measured	calculated
Solubility, mg/l	4300	4700	25	32
Vapour pressure, mm Hg	11.0	11.3	1.8×10^{-4}	3.4×10^{-4}
Soil adsorption coefficient	0.5	2.3	25.1	37.3

At present, however, it is still not possible to predict fully the effects of environmental processes on exposure and hence on the toxic effect in practice. Field investigations are still necessary, as can be well illustrated by the pond studies described by Crossland and Wolff (1988) which can provide a clear demonstration of the important influence of exposure. For example, the pyrethroid insecticide cypermethrin has a high acute toxicity to both fish and aquatic invertebrates in laboratory studies, but is readily metabolised, has a low value for Henry's law constant and a high octanol/water partition coefficient. To clarify how these properties interact in practice, experimental ponds were oversprayed at rates corresponding to those used in agriculture. Consistent with the physico-chemical properties, only 5% of the applied cypermethrin was present dissolved in the pond water. The rest was either sorbed by vegetation and sediment or lost to the atmosphere (Crossland, 1982). Such results show clearly the limitations of acute toxicity tests as indicators of potential environmental impact: they serve only as a tier 1 test to highlight substances requiring further attention. Furthermore these results emphasise the importance of biological availability. Presence in the environment need not in itself be a cause for concern if the substance is not bioavailable.

It should be acknowledged, however, that some aspects of behaviour in the environment require further attention and study. Recently there has been much interest in the possible occurrence of pesticides in ground water, prompted in part by the EEC Drinking Water Directive (No. 80/778/EEC). This directive departs from previous approaches which appear to have served society well in that, without reference to toxicological significance, it stipulates a maximum allowable concentration of 0.1 μg/l for any one pesticide or related substance and 0.5 μg/l for the total of all such compounds. These values when set were effectively at the technical limit of detection, presumably with the objective of ensuring pesticide-free water. However such a Directive gives problems, not only analytical, but also because some water resources already contain pesticides at concentrations higher than 0.1 μg/l. Implementation of the directive by member states has been hesitant. Guidelines for pesticides elsewhere are in line with those applying to other chemicals and are based on toxicological considerations such as those promulgated by the World Health Organisation. The Directive thus represents a virtually unique regulatory situation, the apparent basis of which will become progressively less tenable as analytical methods become more sensitive.

The problems surrounding this Directive have stimulated intensified interest in the routes by which pesticides can reach water bodies. Contamination can clearly occur through accidental spillage or misuse, for example careless disposal of containers or rinsing water. Continued attention to education and training should help to minimise such problems.

Closely related is the subject of waste disposal, which in some cases may be the point of greatest weakness in the environmental management of pesticides. Wastes arising from manufacture lie outside the scope of this paper, although it should be pointed out in passing that every effort should be made to minimise their occurrence through the development of clean technologies, to monitor and document their production where this cannot be avoided and to ensure their destruction or disposal in an environmentally acceptable manner. However wastes can also occur in large quantities after manufacture, notably in the form of obsolete stocks. These can accumulate in various circumstances and solution of the resultant problems by provision of appropriate disposal measures (such as incineration) requires collaborative efforts by all parties who may be involved: producers, suppliers, authorities and agencies.

A further aspect of this general problem is that some past practices, considered acceptable at the time, have given residual problems of soil contamination by persistent and refractory materials. There is a need for reliable, in-situ clean-up methods for such situations. Recent experimental results obtained with chemical treatments (such as the use of KOH/PEG mixtures to degrade organochlorine compounds, Brunelle and Singleton, 1985) give encouragement that such methods may be forthcoming.

In addition, notwithstanding the extensive knowledge already acquired, there is scope for further research on run-off, percolation through soil and in particular the behaviour of chemicals in the lower soil zones and in groundwater. There is evidence that degradative processes, both chemical and microbiological, may be more active in these regions than previously supposed and also different from those in the upper soil zones. For example, Bromilow et al (1986) found that carbamoyloxime pesticide breakdown was much more rapidly in certain anaerobic suboils than in aerobic topsoils as a result of reactions involving ferrous ions. On the other hand soil temperatures may be low during autumm and winter when pesticides vulnerable to leaching reach these zones, so that behaviour is difficult to predict.

Many of the difficulties associated with redistribution in the environment would disappear if application could be targeted more precisely to the intended recipient and rates of application correspondingly reduced. The theoretical potential for such reduction has often been discussed and is indeed enormous (Graham-Bryce, 1977). How far this potential can be realised in practice is a matter for debate, but significant improvements in utilisation are clearly obtainable through methods such as seed treatment (Graham-Bryce, 1988) or further development of electrostatic spraying. For maximum benefit, this last approach should be coupled with complementary development of formulation and dispensing systems as in the ICI "bozzle" concept. Such systems not only offer reduced rates of application; they also eliminate the risk of accidental spillage during mixing and thus provide a greater degree of safety to the operator. Other relatively simple improvements can give substantial advantages: for example modified drums can reduce the risk of pollution from waste material by decreasing the amount which can be left in the drum after pouring out the contents. Similarly, closed systems for transferring pesticide from product container to spray tank can substantially reduce the risk of spillage and hazard to the operator (Lavers, 1989).

Overall, there is a strong case for maintaining efforts across a broad front to reduce uneccessary or unproductive introduction of pesticides in the environment, thereby helping to satisfy the public expectation noted in the introduction, that amounts entering the environment should be curtailed. This of course includes not only improving efficiency of application, but the now well established concepts of integrated pest, disease and weed management involving forecasting and monitoring of infestations, identification of treatment thresholds and complementary employment of different control techniques. Ecological and practical considerations relevant to weed management have recently been reviewed by Mortimer (1987).

ECOLOGICAL EFFECTS

The combination of investigations into toxicity, effects on functions and fate and behaviour now used to evaluate pesticides is generally regarded as providing a reliable safeguard against direct effects in the environment. It is also likely to forewarn against any potential major disturbance to ecological relationships. Such major effects on populations would seem unlikely in cases where a given pesticide is applied to one crop in a rotation on a farm scale at low frequency. Indeed, generally, Bunyan and Stanley (1983) in their well known review, found little evidence that the survival of individual species was threatened by the direct effects of pesticides used on British Farmland.

However, as approaches to assessing direct effects of pesticides have matured, interest in indirect and more subtle ecological effects has increased. Assessing such effects is much more problematical. In principle both lethal and sub-lethal effects of pesticides must be considered at the population, community and ecosystem levels. It is particularly important to relate pesticide effects to any other factors affecting population dynamics in order not to draw erroneous conclusions. This is a complex task: for example recent studies by Kooijman _et al_ (1989) indicate that effects of toxic chemicals on populations of aquatic invertebrates depend strongly on food supply. Even quite considerable sub-lethal effects of chemicals on reproduction will not appear at the population level if the population is food-limited.

The problems of determining what constitutes a significant effect are compounded by the difficulties of experimental measurement and design, particularly in relation to replication and plot size. These difficulties are clearly demonstrated by two pioneering approaches to studying ecological aspects of pesticides use, which nevertheless have given much useful experience and information.

First, the Cereals and Gamebirds Research Project of the Game Conservancy was established some 15 years ago to investigate the effects of pesticides on farm wildlife (Oliver-Bellasis and Sotherton, 1986). Populations of many species have been sampled annually in 100 cereal fields with particular attention to aspects such as the use of key indicator species and the value for game and wildlife of leaving headlands unsprayed. Second, a few years later the Agricultural Development and Advisory Service (ADAS) began the Boxworth project to investigate the ecological and economic implications of different pest, weed and disease management systems for cereals (Hardy, 1986). To avoid problems due to faunal mobility, the experimental design involved a working farmland system, including whole fields and boundaries, which provided large treatment areas and reduced edge effects to a minimum. This inevitably constrained the degree of replication possible. Variability other than that due to treatments was minimised by other measures, such as matching fields between different treatments for all non-treatment operations such as sowing date.

These studies have unquestionably greatly improved understanding of ecological aspects of pesticide use but are inevitably subject to statistical limitations which make it difficult to distinguish effects of pesticide usage from other effects of farming systems and to reach definitive conclusions. Also they are very demanding in terms of land, manpower and other resources.

While, therefore, such investigations must be supported so that understanding of underlying principles continues to improve, it is clear that they cannot be adopted as part of the routine evaluation of pesticides. More pragmatic unamibiguous indicators of adverse impact on ecological relationships are needed, such as alteration of predator/prey balances. Perennial crops offer good opportunities for observing such balances as demonstrated by long term work on control of the spider mite (Panoychus ulmi) on apples summarised by Cranham et al (1984). This work led to a scheme for classifying pesticides according to their relative effects on P. ulmi and its most important predator Typhlodromus pyri, which is capable of regulating the pest to non-injurious levels.

Assessment of even such well defined indices of ecological status requires long-term access to appropriate experimental plots and may prove difficult in routine evaluation. Brown (1989) describes the problems of experimental design, especially those concerning plot size in relation to mobility of pests and beneficial insects. It may be necessary to settle for unreplicated experiments which may reveal the possibility of adverse ecological effects, but cannot indicate their quantitative likelihood.

Similarly in the case of soil, it is necessary to identify key indicator processes which will demonstrate any adverse effects on the ecosystem. Edwards (1988) advocates three complementary methods which assess effects on respiration of undisturbed soil cores, effects on invertebrate biomass and effects on breakdown of organic matter in the form of leaf disks.

Finally, in view of the problems of ecological assessment, it is important to monitor effects on wildlife in practice to provide an additional reassurance. Such monitoring is likely to be increasingly facilitated by the use of biochemical and sub-lethal indicators provided these can be related to biological effects (Walker, 1988).

Ecological questions relating to farming practice, including the use of pesticides, are being posed in a new light in the current situation of food surpluses in developed countries. The relative environmental merits of extensive production with comparatively low yields as against intensive production on a reduced area, thus allowing greater scope for amenity use or conservation, have yet to be resolved. Such considerations underline the very positive ecological and environmental features of pesticides such as broadening the range of choice of land use and minimising soil erosion through the implementation of "conservation tillage" practices.

BIOTECHNOLOGY

No contemporary consideration of environmental effects would be complete without some reference to products from the new biotechnological techniques involving genetic modification. These may include new control agents (for example insect pathogens, bacterial agents and mycoherbicides), herbicide resistant crops and crops resistant to damaging agents. Concerns have been expressed in relation to uncontrolled spread of genetically modified species, transfer of modified genetic material to other species and the possibility that organisms might have unintended and unpredictable harmful properties. Whatever the likelihood of such effects, it is clearly wise to proceed with caution and to ensure that advantage is taken of lessons arising from environmental aspects of conventional pesticides. This is certainly the case in one very important general sense. Some of the environmental safeguards for pesticides were stimulated by experience of widespread use, inlcuding some unfortunate experience. With biotechnology, the regulatory framework is being developed in parallel with the development of the technology. This allows a phased approach in which initial work under contained conditions in the laboratory can be followed by glasshouse and small plot studies leading eventually to restricted field investigations, with monitoring and control safeguards at each stage. Such an approach should be welcomed as allowing the potential benefits of biotechnology to be realised while ensuring appropriate environmental protection.

CONCLUSIONS

There is now a general realisation that environmental protection is essential for the future wellbeing of mankind. Awarness of environmental aspects of pesticides is of long standing, but this new climate of opinion reinforces the need to maintain the highest standards and to review regularly existing safeguards. There is no doubt that producers of pesticides must recognize and respond to this need if they are to succeed in the long term. It is obviously legitimate for society to strive for a continually increasing quality of life and for this to include a progressive reduction in risk of environmental effects from pesticides, at least for those who have a reliable and plentiful food supply. But it is also important that this does not extend to the point where an unreasonable degree of reassurance eliminates valuable benefits to the quality of life provided by pesticides.

Against this background, the following conclusions are offered from the analysis presented above:

- with current safeguards, the environmental hazards of pesticides are modest in the perspective of the overall farming operation and in comparison with other environmental impacts of a rapidly growing global population.
- Some aspects of behaviour in the environment, notably processes in the lower soil/groundwater are not yet adequately understood and require further research.
- Ecological aspects are difficult to assess in routine evaluation and are best addressed by a combination of exploratory research to establish principles, pragmatic assessment of selected key processes and relationships and monitoring any effects on wildlife in practice.
- There is scope for earlier, more deliberate consideration of environmental properties in pesticide development. In future the creation of "designer" molecules having favourable environmental properties may become possible.
- There should be continued efforts to reduce the burden of pesticides in the environment through improved methods of application and formulation and development of integrated pest, disease and weed management and control of waste.

For the present, the familiar tiered or stepwise approach to environmental assessment, described by Brown (1986) appears to work well. Initial determination of basic physicochemical properties and fate in the environment coupled with measurement of acute and chronic toxicity to standard species can be supplemented by more detailed studies on key processes and indicator species together with field monitoring as appropriate for the intended use pattern. Knowledge and experience of environmental aspects of pesticides is however steadily increasing. It is important therefore to review approaches regularly to ensure that they take account of the latest findings and to avoid surprises.

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SESSION 2

NEW HERBICIDES AND PLANT GROWTH REGULATOR MOLECULES

CHAIRMAN	MR J. D. FRYER	
SESSION ORGANISER	MS C. M. KNOTT	
RESEARCH REPORTS		2-1 to 2-12

NEW LOW-RATE SULFONYLUREAS FOR POST-EMERGENCE WEED CONTROL IN CORN

H. L. PALM, P. H. LIANG, T. P. FUESLER, G. L. LEEK, S. D. STRACHAN, V. A. WITTENBACH

E. I. du Pont de Nemours and Company, Inc., Wilmington, DE, USA

M. L. SWINCHATT

Du Pont de Nemours (France) S.A., Paris, France

ABSTRACT

DPX-E9636 (1-(4,6-dimethoxypyrimidin-2-yl)-3-(ethylsulfonyl -2-pyridylsulfonyl)urea) is a new selective post-emergence herbicide for the control of numerous annual and perennial grasses and broad-leaved weeds in *Zea mays*. Toxicology and environmental fate studies so far show favorable results for this sulfonylurea. The low dosage of 5-15 g/ha + surfactant has provided control of noxious perennials such as *Sorghum halepense*, *Elymus repens*, *Cirsium arvensis* and *Cyperus* species. *Setaria*, *Panicum*, *Digitaria*, *Echinochloa*, *Cenchrus* and annual *Sorghum* species are also susceptible. A range of broad-leaved weeds, including species which have become resistant to triazines, show sensitivity. Degradation of DPX-E9636 is rapid and thus flexible crop rotation is anticipated following use of the low rate.

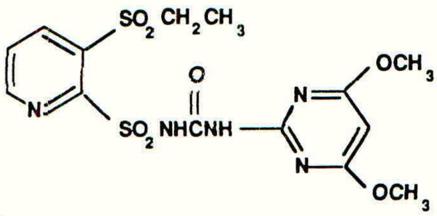
INTRODUCTION

DPX-E9636 is a novel post-emergence herbicide introduced by E. I. du Pont de Nemours & Co., Inc. that offers growers a new alternative for weed control in *Zea mays*. Several perennial and annual grasses frequently escape control by current commercial corn herbicides and a follow-up post-emergence treatment is needed. Cultivations are not always possible or sufficient. Moreover, new regulations are being introduced to limit rates of some current products, further reducing the farmer's options for effective weed control. Some corn farmers are forced to switch to broad-leaved crops in order to use selective post-emergence herbicides that can control problem grasses.

DPX-E9636 has been evaluated in field trials for three years and shows promise in providing farmers a means to safely control a wide spectrum of annual and perennial grasses post-emergence in corn. It has also shown activity on a range of broad-leaved weeds.

CHEMICAL AND PHYSICAL PROPERTIES

Structure:



Common name: Not available yet.

Chemical name: 1-(4,6-dimethoxypyrimidin-2-yl)
-3-(ethylsulfonyl)-2-pyridylsulfonyl)urea

Chemical formula: $C_{14}H_{17}N_5O_7S_2$

Molecular weight: 431.44

Melting point: 176-178^{o}C

Dissociation constant: pK_a = 4.1

Solubility: <10 ppm in unbuffered distilled water at 25^{o}C and
7,300 ppm in buffered pH 7 water at 25^{o}C

Octanol/water partition coefficient: 0.034 at pH 7 at 25^{o}C

TOXICOLOGY

Studies so far show that DPX-E9636 has favorable toxicological properties and does not pose a hazard to the user.

Acute oral LD50 (rat): >5000 mg/kg

Acute dermal LD50 (rabbit): >2000 mg/kg

Eye irritation (rabbit): Moderate irritant

Skin irritation (rabbit): Not an irritant

Skin sensitisation (guinea pig): Not a sensitizer

Ames mutagenicity: Negative

FATE IN SOIL AND THE ENVIRONMENT:

DPX-E9636 degrades rapidly in soil predominantly via chemical pathways. Microbial degradation plays a minor role. Rates of degradation of DPX-E9636 are influenced by pH and the compound is most stable in neutral pH soil and degrades more rapidly in alkaline and acidic soils (Table 1).

TABLE 1. Estimated half-life of DPX-E9636 incubated in non-sterile soil at 30^{o}C in the laboratory.

Soil series	Texture	o.m. (%)	pH	half-life (days)
Miami	silty clay loam	1.7	5.8	1.7
Tama	loam	7.4	6.1	2.8
Toledo	sandy loam	1.8	7.3	4.3
Gardena	silt loam	5.0	8.4	2.7

The anticipated rate of use is low and degradation is rapid so that DPX-E9636 in the soil disappears quickly. Therefore no restrictions are expected for crops grown in normal rotation following application of DPX-E9636 at recommended rates in corn.

Results in Table 2 indicate rapid chemical degradation in aqueous solutions of varying pH.

TABLE 2. Half-life of DPX-E9636 in aqueous solutions at 25^{o}C.

pH	half-life (days)
5	4.6
7	7.2
9	0.3

Soil mobility studies indicate that DPX-E9636 poses very low risk of leaching into ground water. The low octanol/water partition coefficient of 0.034 at pH 7 suggests minimal risk of bioaccumulation.

MODE OF ACTION AND SELECTIVITY

DPX-E9636, like other sulfonylurea herbicides, inhibits cell division and growth by inhibiting the plant enzyme acetolactate synthase thereby blocking branched chain amino acid biosynthesis (Beyer et al., 1988). The initial symptoms of DPX-E9636 activity are observed in the meristematic tissues of treated plants. There is early cessation of growth of sensitive grass and broad-leaved species followed by chlorosis, necrosis and plant death.

Excellent crop safety has been observed on corn at 2-4 times the expected rate of use. Crop tolerance to DPX-E9636 is based on the differential rate of metabolism of the active compound to inactive metabolites in corn compared to sensitive species (Sweetser et al., 1982). DPX-E9636 has a half-life of only 6 hours in corn leaves, whereas in sensitive species such as Alopecurus myosuroides, Sorghum halepense, and Sorghum bicolor the half-lives are much longer (Table 3). In laboratory tests there is a good correlation between injury and half-lives, although Sorghum halepense appears to be more sensitive than one would expect from the half-life.

TABLE 3. Comparison of the sensitivity of crops and weeds to DPX-E9636 & metabolism rates.

Plant Species	% Injury at 16 g a.i./ha	GI50* g a.i./ha	Metabolic half-life (h)
Zea mays	5	79	6
A. myosuroides	86	2	46
S. halepense	100	<1	25
S. bicolor	100	<1	52

*GI50 = Rate of DPX-E9636 that results in 50% visible injury under laboratory conditions.

EFFICACY

It has been shown that adjuvants such as a non-ionic surfactant or a crop oil concentrate play a key role in achieving consistent performance and enhanced activity on certain species. The suggested rates of use for DPX-E9636 are from 5 to 15 g a.i./ha with a suractant at 0.1% to 0.25% V/V. In trials in many countries this dose range has given commercially acceptable control of the following weed species:

Perennials

- Cirsium arvense
- Cyperus esculentus
- Cyperus rotundus
- Cyperus serotinus
- Elymus repens
- Rumex crispus
- Sorghum halepense

Annual Grasses

- Avena fatua
- Brachiaria platphylla
- Cenchrus incertus
- Digitaria horizontalis
- Digitaria ischaemum
- Digitaria sanguinalis
- Echinochloa crus-galli
- Eriochloa villosa
- Leptochloa spp.
- Lolium multiflorum
- Panicum capillare
- Panicum dichotomiflorum
- Panicum maximum
- Panicum miliaceum
- Panicum texanum

Annual Broad-leaved Species

- Abutilon theophrasti
- Amaranthus hybridus
- Amaranthus retroflexus
- Amaranthus tuberculatus
- Cleome monophylla
- Fumaria officinalis
- Galinsoga parviflora
- Galium aparine
- Matricaria spp
- Mentha arvensis
- Mercurialis annua
- Papaver rhoeas
- Raphanus raphanistrum
- Sinapis arvensis
- Stellaria media

Setaria faberi
Setaria glauca
Setaria verlicillata
Setaria viridis
Sorghum almum
Sorghum bicolor
Tagetes minuta
Tribulus terrestris

Activity on annual species is most effective when applied early post-emergence with weeds at 2-5 leaf stage. Application to annual grasses should be before tillering.

Perennial weeds need to have enough shoot growth to absorb the spray. Shoots that emerge after treatment will not be affected. Split-dose applications of (8 + 8) or (10 + 10) g a.i./ha + surfactant have been particularly effective on late-emerging shoots of perennials or late-emerging Digitaria.

DPX-M6316 at 5-8 g a.i./ha can be added to control a broader spectrum (Amuti et al., 1987). It significantly improves the activity on the following broad-leaved weeds.

Chenopodium album
Chenopodium ficifolium
Polygonum convolvulus
Polygonum lapathifolium
Polygonum persicaria

CONCLUSIONS

DPX-E9636 can become an integral part of corn production in the near future. All indications suggest that it possesses favorable toxicology; that it is unlikely to bioaccumulate; and that it is unlikely to leach into the ground water or endanger the environment as a whole. The rapid soil metabolism provides for rotational crop flexibility.

The wide spectrum of activity by DPX-E9636 allows it to be considered a basic tool for weed control in corn. With the possible restrictions on rates and use of some current standard products in some countries, DPX-E9636 offers some new options for the corn farmer. It could be:

- an alternative to existing pre-plant or pre-emergence standard herbicides that also offers control of perennials such as Sorghum halepense, Elymus repens, Cyperus and Rumex spp.

- a new tool to use with standard practices that improves the control of problem grasses and triazine-resistant, broad-leaved weeds.

- a post-emergence ‘rescue’ treatment for controlling annual grass and broad-leaved weeds if the pre-plant or pre-emergence treatments fail and

- a more desirable alternative to the high rates of use needed for pre-emergence herbicides on high organic soils.

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SL-950, A NOVEL SULFONYLUREA HERBICIDE FOR CORN

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ABSTRACT

SL-950, 2-(4,6-dimethoxypyrimidin-2-ylcarbamoylsulphamoyl)-*N*,*N*-dimethylnicotinamide, is a novel post-emergence herbicide for corn (*Zea Mays*) and is under development by Ishihara Sangyo Kaisha Ltd. In the greenhouse and field SL-950 has proved successful in controlling a wide range of weeds in corn at very low rates of 40 to 60 g a.i./ha. SL-950 is outstanding since it can control several troublesome perennial grasses including *Sorghum halepense* and *Elymus repens* at the same rates required for annual weeds. Most corn varieties can tolerate post-emergence applications with at least a fourfold safety margin relative to the rate required for weed control, but some sweet varieties of corn are more susceptible. This paper discloses product chemistry, physico-chemical properties, toxicological profile, and biological effects of SL-950.

INTRODUCTION

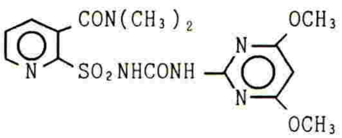
Corn (*Zea mays*) growers are unable to control annual and perennial weeds simultaneously with any herbicide currently available, and separate applications of more than two different types of herbicides are made. We have recently invented a new type of corn herbicide which provides excellent control of not only annual grasses and broad-leaved weeds but also troublesome perennial grasses such as *Sorghum halepense* and *Elymus repens* with one application. Three years of field studies carried out over the world have confirmed the excellent results for biological performance which had been obtained from the preliminary evaluation tests in the greenhouse and in small scale outdoor tests.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical name (IUPAC) : 2-(4,6-dimethoxypyrimidin-2-ylcarbamoyl sulphamoyl)-*N*,*N*-dimethylnicotinamide

Common name : Nicosulfuron

Chemical Structure :



Empirical formula : $C_{15}H_{18}N_6O_6S$ Molecular weight : 410.41

Appearance : Colourless crystals Melting point : 172-173°C

Dissociation constant (pKa) : 4.6 at 25 ℃

Water solubility (in buffer) : 44 ppm (pH 3.5), 22,000 ppm (pH 7.0)

FORMULATION

SL-950 is formulated as suspension concentrate (SC) of 40g/l and as a water dispersible granule (WG) of 75%.

TOXICOLOGY (Active ingredient)

Acute oral LD_{50} (Male mouse)	>5,000 mg/kg
Eye effect (Rabbit)	Moderate eye irritant
Skin sensitisation (Guinea pig)	Not a sensitiser
4 Week subacute (Rat and mouse)	No adverse effect up to 30,000ppm in the diet
Mutagenicity	
Gene mutation (Ames test)	
TA100, TA98, WP2uvrA	Negative
DNA repair (Rec-assay)	
B. sub. rec $^{-}$	Negative
Chrom. aberration	
CHL (in vivo)	Negative
Micronucleus (Mouse)	Negative
Sperm morphology	Negative
Fish, acute toxicity (Carp)	LC_{50}(24-96 hrs) > 10 ppm

MODE OF ACTION

The mode of action of SL-950 is very similar to that of the other sulfonylurea compounds which have been already in the market or under development. SL-950 strongly inhibits the enzyme reaction of acetolactate synthase in both susceptible and resistant plants. SL-950 is rapidly absorbed by the roots and foliage of treated plants and translocated through the xylem and phloem. Susceptible plants stop growing immediately after application, but other symptoms cannot be observed until four to five days later. The first visible symptom is discoloration of the young developing leaves followed by necrosis which spreads slowly to the whole plants. Treated plants are killed within 20 to 25 days under normal conditions, but it may take longer under cooler conditions or for some perennial species. In some grass species, for example *Sorghum halepense* and *Digitaria sanguinalis*, anthocyanin formation can sometimes be seen in older leaves. Surfactants increase the activity of SL-950 especially on certain gramineous weeds.

RESULTS

Herbicidal activity : post-emergence application

This test was carried out using standard screening methods in the greenhouse. As shown in Table 1, SL-950 controls a far wider weed spectrum than existing corn herbicides such as atrazine. It showed a general tendency to control gramineous weeds more effectively than broad-leaf weeds. Broad-leaved species such as *Sida spinosa*, *Abutilon theophrasti*, and *Cassia tora* showed moderate resistance to SL-950 at the recommended rate of 40 to 60g a.i./ha.

TABLE 1. Percentage control of weed species with SL-950 post-emergence

Weed species & leaf stage		g a.i./ha SL-950 62.5	atrazine 1000
Digitaria sanguinalis	2	○	×
Setaria viridis	2	◎	×
Eleusine indica	3	◎	◎
Echinochloa crus-galli	3	◎	○
Lolium multiflorum	2	◎	×
Avena fatua	3	◎	×
Poa annua	4	◎	○
Cyperus microiria	3	◎	○
Xanthium strumarium	2	◎	△
Ipomoea hispida	2	○	◎
Polygonum blumei	2	◎	◎
Sida spinosa	2	△	◎
Abutilon theophrasti	1	△	×
Chenopodium album	2	○	◎
Amaranthus viridis	3	◎	◎
Solanum nigrum	2	◎	◎
Portulaca oleracea	3	◎	◎
Cassia tora	1	△	△
Sorghum halepense (rhizome)	4-5	○	×
Elymus repens	3-5	○	×
Cynodon dactylon	15cm	×	×
Cyperus rotundus	5-6	○	×

◎ 95 ～ 100%　　△ 50 ～ 70%
○ 75 ～ 95%　　× below 50%

SL-950 was more effective when applied post-emergence before the 4 leaf stage of the weeds (Fig.1). Foliage treatment with SL-950 was also more effective than soil treatment. Weed seeds could germinate after soil treatment with SL-950, however the seedlings soon turned necrotic and died.

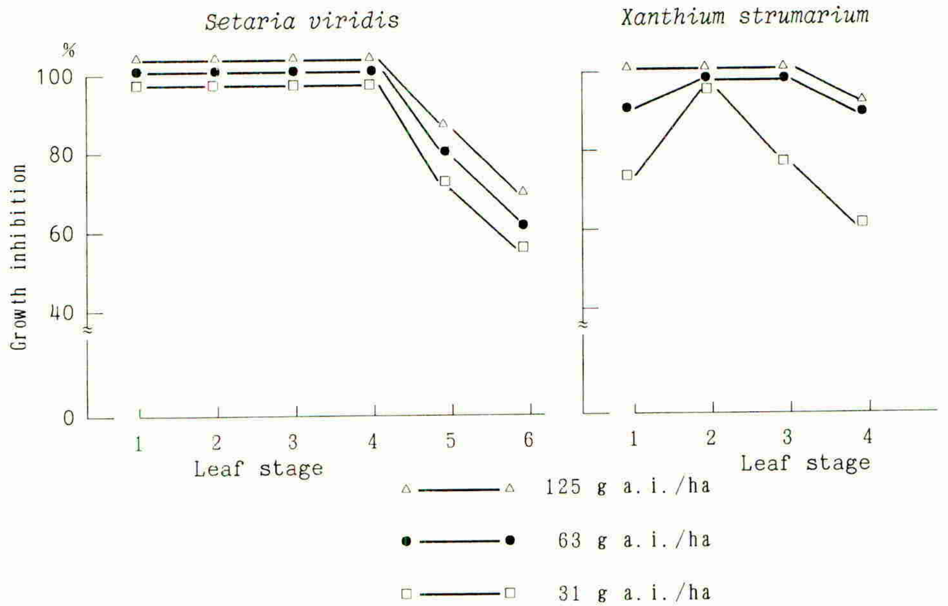


Fig.1. Growth inhibition of weed species at various leaf stages by SL-950.

Control of annual weeds and *Sorghum halepense*, France and Italy

Field trials were carried out in the major corn growing regions in northwest and southwest France and north Italy with relevant target weeds and results are shown in Table 2.

In France, weed control with SL-950 at 40g a.i./ha was complete by four weeks after treatment. However, there was some recovery of *Lolium italicum* and *Chenopodium album* which were moderately resistant to SL-950, and increasing dose rate gave little improvement of efficacy. In Italy, SL-950 gave a good control of a dense infestation of *Amaranthus retroflexus* at 40 g a.i./ha 28 days after treatment, but gave poor control of *Chenopodium album* and *Echinochloa crus-galli*. The density of weed population and shading with *Amaranthus retroflexus* were probably the factors influencing the low level of control. There was no improvement of the efficacy at increased rates.

In France, by four weeks after treatment SL-950 at 20 to 40g a.i./ha gave 70 to 80% control of *Sorghum halepense* which germinated from rhizomes and was not controlled by alachlor/atrazine at all. In Italy, the efficacy was inferior to that obtained in France, and there was no improvement when rates were increased.

TABLE 2. Percentage control of annual and *Sorghum halep ense* post-emergence in France and Italy.

Weed species	Herbicide & rate g a.i./ha			
	SL-950			Standard products
	20	40	80	Normal rates
Southwest France (29 DAT)				(a)
Setaria viridis	85	95	100	100
Panicum miliaceam	92	99	100	82
Amaranthus retroflexus	98	100	100	98
Chenopodium album	83	90	100	90
Sorghum halepense (Rhizome)	65	80	93	0
(Seed)	90	95	100	100
Northwest France (29 DAT)				(a)
Lolium italicum	75	90	96	100
Avena fatua	90	92	100	92
Rumex obtusifolius	58	77	95	100
North Italy (44 DAT)				(b)
Amaranthus retroflexus	90	92	95	82
Chenopodium album	23	20	53	20
Echinochloa crus-galli	40	50	60	20
Sorghum halepense (Rhizome)	63	73	70	3

(a) atrazine/alachlor 3360/1500g a.i./ha
(b) atrazine 800g a.i./ha plus oil 1.0 ℓ /ha

Crop safety

Several corn cultivars were treated at 5 to 6, 4, and 3 to 4 leaf stages in Italy, southwest France, and northwest France, respectively. SL-950 at 160g a.i./ha showed complete safety in Italy. Although in France some crop damage was observed on some cultivars at the highest rate, they were considered to be acceptable with virtually complete recovery after four weeks. The safety margin was defined as follows : –

$$\text{Safety margin} = \frac{\text{Rate required for 20\% crop damage of a given culitivar}}{\text{Rate required for 95\% weed control}}$$

TABLE 3. The safety margin of SL-950 for corn.

Rate	Safety margin		
g a.i./ha	Italy	Northwest France	Southwest France
40	> 4	> 4	> 4
80	> 2	> 2	> 2

Movement and dissipation in soil

Soil samples were taken 15, 30, and 60 days after treatment from sandy loam soil which was treated with 125g a.i./ha of SL-950. Soil samples from depth at 5cm intervals were bioassayed using a very sensitive crop, oilseed rape and the visual percentage of shoot growth inhibition was recorded. Fig. 2 shows that most of SL-950 remained in the upper layer of 15cm from the surface, and little moved down to 30cm depth. The growth of oilseed rape planted in all the soil layers down to 10cm deep was significantly reduced until 30 days after treatment. Two months after treatment, the oilseed rape growth was not affected in any of the layers sampled except for slight inhibition in the 0 to 5cm layer and no residual activity was detected 3 months after treatment.

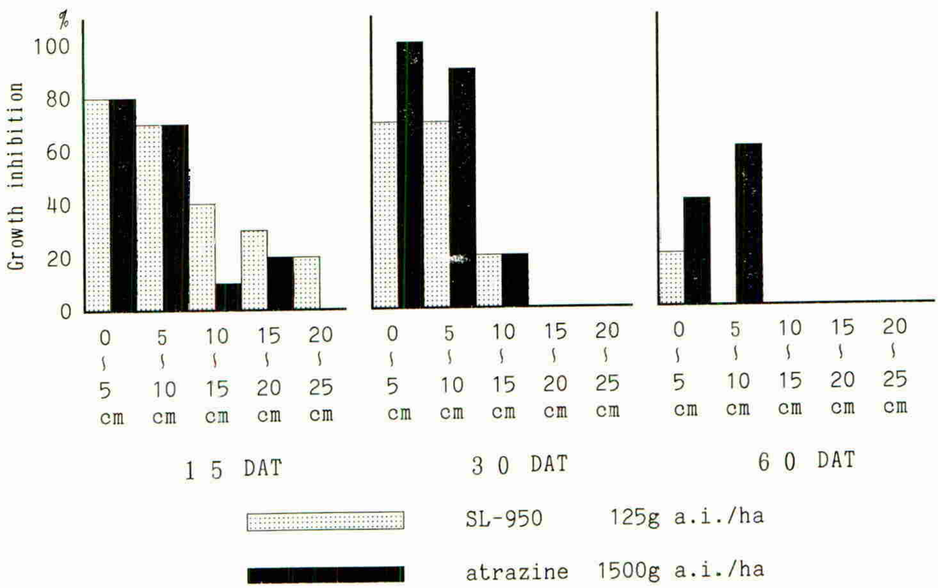


Fig.2. Residues of SL-950 in soil layers detected by oilseed rape bioassay.

CONCLUSIONS

The corn herbicide SL-950 has the following special features :—

- the most striking is control of heavy infestations of rhizomes of *Sorghum halepense* and *Elymus repens*.
- it controls a very wide weed spectrum including annual and perennial grasses, broad-leaved weeds.
- the suggested rate of use is 40g a.i./ha or below — far lower than rates recommended for existing corn herbicides.
- flexibility of timing; application at advanced weed growth stages.
- limited carry-over tests show no adverse effect on succeeding crops, however, further studies including soil type, pH, organic matter content and temperature are needed.
- excellent safety to the corn crop with only transient damage which disappeared after four weeks.

SN 106 279 - A NEW HERBICIDE FOR USE IN WINTER CEREALS

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ABSTRACT

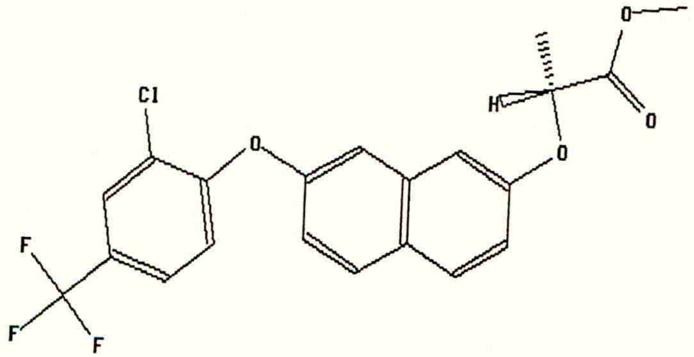
SN 106 279 is a new selective herbicide for use in winter cereals. The activity spectrum of SN 106 279 includes *Veronica* spp., *Viola* spp., *Lamium* spp. and other important broad-leaved weeds. Best results have been obtained with post-emergence applications of dose rates between 100 and 500 g a.i./ha. This paper discloses product chemistry, first biological and physico-chemical profiles of SN 106 279.

INTRODUCTION

SN 106 279 is a new herbicide discovered by Schering AG, Berlin, West Germany. The primary use is for the post-emergence control of broad-leaved weeds in winter cereals. Field trials conducted since 1985 have demonstrated good activity against several important species under different climatic conditions. This paper describes the properties of SN 106 279 and presents data from laboratory, glasshouse and field testing programmes.

CHEMICAL AND PHYSICAL PROPERTIES

Structure:



Chemical name (IUPAC): Methyl (R)-2(7-(2-chloro-α,α,α-trifluoro-*p*-tolyloxy)-2-naphthyloxy)propionate

Molecular formula:	$C_{21} H_{16} Cl F_3 O_4$
Molecular weight:	424,808
Appearance:	Technical product: yellow liquid
Vapour pressure:	2.39×10^{-6} Pa at 25° C
Solubility:	at 20° C: water 0.7 mg/l ethanol 870 g/l methanol 850 g/l acetone 870 g/l

TOXICOLOGY	Rat: (male)	Acute oral LD_{50} (mg/kg) of technical material > 400
	Rat: (male)	Acute dermal LD_{50} (mg/kg) of technical material » 400

MODE OF ACTION

SN 106 279 has relatively low herbicidal activity following application to soil and is taken up principally by plant leaves. The first visible symptoms appear some hours after application. It exhibits diphenyl ether type symptoms and it causes necrosis of shoot and root meristems and rapid desiccation of stems and leaves following post-emergence treatment of sensitive species. The target site so far is not proved.

MATERIALS AND METHODS

Glasshouse and field trials

For glasshouse screening SN 106 279 was applied pre- or post-emergence using trays filled with sterile, sandy loam soil. Experiments were maintained in a 12 to 14 h photoperiod with a temperature of 20 to 25° C. Visual assessment of crop damage and weed control was made 21 to 28 days after spray application.

Field experiments were performed between 1985 and 1989 at Schering Research and Field Stations in Europe and in the USA.

For field screening and evaluation,technical grade SN 106 279 was formulated as an EC containing 422 g a.i./l. Also a 20 % EC was available. In addition, various WP formulations were tested.

The size of replicated randomised field plots was between 10 and 20 m². The compound was applied in spray volumes of 200 to 500 l/ha. Weed species were either sown in rows across the plots or were present as indigenous populations. Spray application was carried out employing small plot spraying equipment. Percentage control of each species was assessed by visual score.

Preliminary soil mobility experiments

Studies were carried out according to the soil thick-layer chromatography method described by Gerber *et al.*, (1970), Chu-Huang Wu and P.W. Santelmann, (1975).

RESULTS AND DISCUSSION

Glasshouse trials

Under glasshouse conditions SN 106 279 controlled non-temperate broad-leaved weeds such as *Abutilon theophrasti*, *Ipomoea* spp., *Sesbania exaltata*, *Cassia obtusifolia*, *Datura* spp., *Solanum* spp., *Polygonum* spp., *Portulaca* ssp. and temperate weed species such as *Brassica* spp., *Matricaria chamomilla*, *Viola* spp., *Chrysanthemum segetum* and *Veronica persica* with dose rates between 10 and 100 g a.i./ha post-emergence. Rice, maize, wheat and barley were tolerant (Table 1). For the control of weed species in pre-emergence trials more than 100 g a.i./ha were required (Table 1).

Field trials

Since 1987, SN 106 279 has been evaluated by Schering at field stations in the major cereal-growing areas of West Europe. Work has concentrated on those areas known for spring application of herbicides to autumn-sown cereals, but a small number of trials have also been carried out in spring-sown crops. In addition, SN 106 279 has been used as an autumn/winter treatment in autumn-sown cereals. Although this application timing is not as widely used as spring treatment, it is of interest locally, particularly in the United Kingdom.

The spectrum of activity of SN 106 279 is now fairly well established and the results obtained from experimental work carried out in the period 1987 - 1989 are shown in Tables 2 and 3. Efficacy on a number of minor species requires confirmation.

Data is limited for control of *P. lapathifolium* and *S. arvensis* by SN 106 279 at 125 g a.i./ha. Weed species only moderately well controlled at 500 g a.i./ha include *Stellaria media*, *Matricaria* spp., *Papaver rhoeas*, *Capsella bursa-pastoris* *Chenopodium album* and *Aphanes arvensis*.

Early indications are that satisfactory control of *Amaranthus retroflexus* may also be possible with 125 g a.i./ha.

Crop safety in winter wheat has been good, but in winter barley some transient chlorosis or necrosis has been observed, particularly from 500 g a.i./ha applied during warm weather conditions. However, this phytotoxicity was normally less than that caused by standard herbicides. Efficacy and crop safety in spring-sown crops requires confirmation.

Control of several important species is considerably improved by application in the autumn/winter period (Table 3).

TABLE 1. Glasshouse results: mean crop damage/weed control scores for SN 106 279. Post-emergence: temperate species (10 experiments), non-temperate species (4 experiments). Pre-emergence: temperate species (6 experiments).

Species	Mean crop damage/weed control score +					
	Post-emergence Rate g a.i./ha			Pre-emergence Rate g a.i./ha		
	100	30	10	1000	300	100
Temperate						
Hordeum vulgare	1	0	0	0	0	0
Triticum aestivum	1	0	0	0	0	0
Zea mays	1	0	0	0	0	0
Matricaria chamomilla	4	3	2	4	4	2
Viola spp.	4	4	3	4	2	0
Chrysanthemum segetum	4	4	3	4	3	0
Veronica persica	4	4	3	4	3	1
Brassica spp.	4	4	3	3	3	0
Non-temperate						
Oryza sativa	0	0	0			
Zea mays	1	0	0			
Abutilon theophrasti	4	4	3			
Ipomoea spp.	4	4	3			
Sesbania exaltata	4	4	3			
Cassia obtusifolia	4	3	2			
Datura spp.	4	3	2			
Solanum spp.	4	4	3			
Polygonum spp.	4	4	3			
Portulaca oleracea	4	3	2			

\+ Key: 0 = normal plant stand
1 = slight effect, or 1 to 25 % damage
2 = moderate effect, or 26 to 75 % damage
3 = strong effect, or 76 to 90 % damage
4 = total plant destruction, or 91 to 100 % damage

TABLE 2: Weed control spectrum of SN 106 279 applied in spring to autumn-sown cereals (95 - 100 % control)

125 g a.i./ha	250 g a.i./ha	500 g a.i./ha
	in addition	in addition
Veronica arvensis	Veronica hederifolia	Polygonum persicaria
Veronica persica	Myosotis arvensis	Galium aparine
Viola arvensis		
Lamium amplexicaule		
Lamium purpureum		
Polygonum convolvulus		
Polygonum lapathifolium*		
Sinapis arvensis*		

* requires further confirmation

TABLE 3: Weed control spectrum of SN 106 279 applied in autumn/winter to autumn-sown cereals (95 - 100 % control)

125 g a.i./ha	250 g a.i./ha	500 g a.i./ha
Veronica arvensis	in addition	in addition
Veronica persica	*Matricaria chamomilla*	*Myosotis arvensis*
Veronica hederifolia	*Galium aparine*	
Viola arvensis		
Lamium purpureum		
Sinapis arvensis		
Matricaria inodora		
Capsella bursa-pastoris		

At 500 g a.i./ha insufficient activity has been recorded against *Stellaria media*. No information has been generated, to date, on the degree of efficacy of autumn/winter applications for control of *Lamium amplexicaule*, *Papaver rhoeas*, *Chenopodium album* and *Aphanes arvensis*.

In general, the efficacy and crop safety of SN 106 279 has compared very favourably with that of available standard herbicides with a similar spectrum of activity.

Preliminary soil mobility experiments

The results of the study indicate that SN 106 279 has relatively low mobility under these conditions (Table 4).

TABLE 4: Mobility of SN 106 279 in soil thick-layer chromatography experiments

Soil type	Indicator species			
	M. chamomilla		*V. persica*	
	Movement time (minutes)	R_f	Movement time (minutes)	R_f
sandy soil, pH 5.5 0.5 % organic matter	85	0.11	65	0.17
sandy loam, pH 7.5 5 % organic matter	85	0.06	120	0.07

R_f: Relative mobility value with water as a solvent

CONCLUSIONS

SN 106 279 provides good post-emergence control of temperate and non-temperate broad-leaved weeds with dose rates between 100 and 200 g a.i./ha. Physico-chemical parameters and first leaching studies indicate low soil mobility. No carry-over problems are to be expected in following crops. The compound has potential as a partner with other cereal herbicides with complementary weed spectra.

ACKNOWLEDGEMENTS

We would like to acknowledge the work of our colleagues in Schering Research and Biological Development.

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Gerber, H. R.; Ziegler, P.; Dubach, P. (1970) Leaching as a tool in the evaluation of herbicides. Proceedings 1970, British Crop Protection Conference Weeds, 1, 118-125.

S-23121 - A NEW CEREAL HERBICIDE FOR BROAD-LEAVED WEED CONTROL

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ABSTRACT

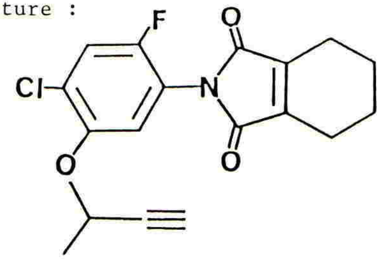
S-23121, N-[4-chloro-2-fluoro-5-[(1-methyl-2-propynyl)oxy]phenyl]-3,4,5,6-tetrahydrophthalimide is a new pre- and post-emergence herbicide for broad-leaved weed control in cereals. Results from field evaluations in the United Kingdom, France and West Germany are summarised. S-23121 is effective against a wide range of broad-leaved weeds at 10-20 g a.i./ha pre-emergence in the UK and post-emergence in France and West Germany. It is particularly effective against troublesome weeds such as *Galium aparine*, *Veronica* spp. and *Viola* spp. Combinations with other herbicides such as isoproturon, mecoprop and metsulfuron-methyl broaden the weed control spectrum. Applied at these doses, S-23121 has good crop safety.

INTRODUCTION

S-23121, discovered by the Sumitomo Chemical Co., is a new herbicide for cereal crops, and is being developed for the pre- and post-emergence control of broad-leaved weeds. It is currently under field evaluation in various countries. This paper describes the properties of S-23121, and summarises the results of greenhouse tests in Japan, and field trials in the UK, France and West Germany.

PHYSICAL AND CHEMICAL PROPERTIES

Structure :



Molecular formula : $C_{18}H_{15}ClFNO_3$

Molecular weight : 347.8

Melting point : 115 - 116.5 °C

Vapour pressure : 0.28 mPa (20 °C)

Density : $d_4^{25} = 1.39$ g/cm^3

Chemical name:: (RS)-N-[4-chloro-2-fluoro-5-[(1-methyl-2-propynyl)oxy]phenyl]-3,4,5,6-tetrahydrophthalimide

Appearance : White to light brown crystalline solid

Solubility (at 23 °C) :

Water	:	< 1 ppm
Xylene	:	20 - 30 %
Hexane	:	< 1 %
Acetone	:	> 50 %
Methanol	:	5 - 10 %
Ethyl Acetate	:	33 - 50 %

TOXICOLOGY OF TECHNICAL MATERIAL (Preliminary)

Acute oral (LD50)	rat	:	>5000 mg/Kg
Acute dermal (LD50)	rat	:	>2000 mg/Kg
Fish toxicity (LC50,48h)	killifish	:	>1.0 ppm
	carp	:	>1.0 ppm
Skin irritation	rabbit	:	no irritant
Eye irritation	rabbit	:	minimal irritant
Mutagenicity (Ames test)		:	negative

MODE OF ACTION

S-23121 is a contact-type herbicide. When applied to foliage, it is readily absorbed into plant tissues, and rapid necrosis or desiccation of stems and leaves is induced in the presence of light and oxygen. Soil application induces shoot necrosis. Sato et al., (1987a, b) reported that the physiological and biochemical action of S-23142 an N-phenylimide herbicide, in which the 1-methyl-2-propynyl of S-23121 is substituted for 2-propynyl, is similar to that of diphenyl ether herbicides. Like other chemically similar herbicides, S-23121 promotes the accumulation of porphyrin in the cells, leading to the peroxidation of lipids.

MATERIALS AND METHODS

Greenhouse Tests

In greenhouse tests conducted in Japan, S-23121 was applied as a 10% EC formulation. Post-emergence application was 20-30 days after seeding, when crops and weeds were at the 1-4 leaf growth stage. Visual assessment of herbicidal activity and crop safety were made 20-30 days after treatment (DAT) using a scale 0 (no effect) - 10 (completely killed).

Field Trials

S-23121 (10% S.C. formulation) was applied alone or in tank-mixture with isoproturon, mecoprop or metsulfuron-methyl and compared with standard treatments in winter wheat and winter barley. Weed control was assessed visually on a percentage scale, or by weed counts. Crop tolerance was assessed by scoring crop vigour, leaf thinning and injury. The field evaluations were carried out as follows:

Application timing	Country	Treatment DAS*	Crop stage**	Visual assessment Crop DAT	Visual assessment Weed DAT
Pre-emergence	UK	0- 7		14-200	200-230
Early post-emergence	UK, France West Germany	40-120	GS 13-24	40-200	30-200
Post-emergence	West Germany	150-200	GS 21-30	20-100	30-100

* DAS: days after seeding.
** Growth stage at the time of treatment (Zadoks' scale).

RESULTS

Greenhouse Tests

S-23121 is highly effective against broad-leaved species, but has relatively low activity against grass weeds and crops (Table 1). There is clear selectivity between graminaceous crops (wheat and maize) and broad-leaved weeds. Abutilon theophrasti, Ipomoea spp., Solanum nigrum and Viola arvensis are highly susceptible, and Galium aparine, a troublesome weed in cereal crops, is also controlled. Sorghum halepense and Setaria viridis are moderately susceptible.

TABLE 1. Activity and crop safety for S-23121 post-emergence (greenhouse tests)

Species	S-23121 (g a.i./ha)		
	1	4	16
Cotton	9.7	10.0	10.0
Soybean	4.3	7.0	9.3
Sugar beet	7.0	9.2	9.6
Maize	1.0	2.3	4.0
Wheat	1.3	2.0	3.9
Abutilon theophrasti	10.0	10.0	10.0
Cassia obtusifolia	0.0	5.5	10.0
Galium aparine	4.4	7.8	9.8
Ipomoea spp.	9.3	9.7	10.0
Solanum nigrum	10.0	10.0	10.0
Stellaria media	6.5	9.1	9.7
Veronica persica	6.7	9.5	10.0
Viola arvensis	8.8	9.8	9.9
Xanthium strumarium	5.3	10.0	10.0
Alopecurus myosuroides	0.2	0.8	1.8
Avena fatua	0.5	1.8	5.1
Echinochloa crus-galli	0.7	2.3	5.0
Setaria viridis	1.7	4.3	8.3
Sorghum halepense	2.0	4.7	8.0

Score : 0 (no effect) - 10 (completely killed)
0-3 acceptable crop phytotoxicity
7-10 acceptable herbicidal activity

Field Trials

Pre-emergence: Table 2 shows the mean values for crop phytotoxicity and weed efficacy of S-23121 in the UK field trials following pre-emergence treatment. S-23121 at 10-20 g a.i./ha gave excellent control of seven broad-leaved weeds which are common and troublesome in Europe. It gave poor control of Alopecurus myosuroides, but was moderately effective against Poa annua. Crop damage was slight and variable, and any phytotoxicity was transient.

S-23121 has complementary activity to isoproturon, and such mixtures were highly effective against most grass and broad-leaved weeds, and did not induce crop injury.

Post-emergence: In France (Table 3), S-23121 applied early post-emergence at 10 g a.i./ha was effective on five important broad-leaved weeds which are sometimes difficult to control with herbicides currently avalable.

TABLE 2. Percentage weed control and crop effect for S-23121 applied pre-emergence in the UK, (Number of trials)

Crops and weeds	S-23121		S-23121 + Isoproturon		Isoproturon
	10	20	10+1000	20+1000	1000
			g a.i./ha		
Wheat	5 (4)	7 (4)	4 (2)	6 (2)	2 (2)
Barley	3 (4)	3 (4)	2 (2)	5 (2)	1 (2)
Alopecurus myosuroides	38 (4)	51 (4)	90 (4)	89 (4)	78 (4)
Poa annua	56 (2)	77 (2)	97 (2)	98 (2)	91 (2)
Capsella bursa-pastoris	95 (1)	100 (1)	100 (1)	100 (1)	83 (1)
Matricaria spp.	85 (3)	99 (3)	99 (2)	100 (2)	99 (2)
Myosotis arvensis	94 (1)	99 (1)	98 (1)	99 (1)	52 (1)
Raphanus raphanistrum	93 (1)	97 (1)			
Stellaria media	77 (4)	92 (4)	98 (1)	100 (1)	98 (1)
Veronica persica	93 (3)	97 (3)	99 (2)	98 (2)	30 (2)
Viola arvensis	90 (3)	96 (3)			

TABLE 3. Percentage weed control and crop effect for S-23121 applied early post-emergence in France, (Number of trials)

Crops and weeds	S-23121		S-23121 + IPU	S-23121 + CMPP	Ioxynil + IPU + CMPP	Isoxaben + IPU
	10	20	10+1800	10+1150	400+1950+950	76+1800
				g a.i./ha		
Wheat	1 (11)	5 (6)	4 (9)	2 (3)	7 (5)	3 (5)
Barley	2 (14)	5 (8)	3 (3)	9 (5)	10 (7)	3 (7)
Alopecurus myosuroides	22 (9)	42 (4)	95 (9)		92 (9)	89 (9)
Galium aparine	99 (7)	99 (5)	99 (4)	100 (1)	92 (4)	58 (4)
Papaver rhoeas	86 (9)	94 (5)	99 (5)	100 (2)	99 (5)	98 (5)
Stellaria media	99 (5)	99 (3)	100 (1)	100 (3)	100 (1)	100 (1)
Veronica hederifolia	96 (6)	98 (4)	98 (2)	100 (2)	96 (3)	93 (2)
Viola spp.	99 (5)	100 (3)	99 (4)	97 (1)	39 (4)	53 (4)

IPU = Isoproturon ; CMPP = Mecoprop

Control of Galium aparine and Viola spp., was superior with S-23121 alone to combinations of ioxynil + isoproturon + mecoprop or isoxaben + isoproturon.

TABLE 4. Percentage weed control and crop effect for S-23121 applied post-emergence in West Germany, (Number of trials)

Crops and weeds	S-23121		S-23121 + IPU	S-23121 + CMPP	S-23121 + MSM	Dichlorprop + Ioxynil
	10	20	10+1500	10+1120	10+6	2030+280
				g a.i./ha		
Wheat	1 (17)	1 (14)	0 (13)	2 (7)	2 (9)	0 (13)
Barley	0 (3)	0 (7)			0 (3)	
Alopecurus myosuroides			93 (11)			
Apera spica-venti	12 (7)	13 (9)	87 (9)	0 (2)	83 (4)	0 (2)
Galium aparine	87 (19)	89 (16)	92 (11)	95 (11)	81 (7)	92 (9)
Lamium spp.	92 (11)	99 (12)	98 (6)	99 (8)	99 (3)	98 (2)
Matricaria chamomilla	55 (15)	53 (17)	99 (7)	81 (5)	100 (8)	96 (5)
Stellaria media	69 (18)	64 (26)	97 (7)	98 (9)	100 (9)	92 (2)
Veronica persica	94 (2)	97 (2)	100 (1)	96 (2)		
Viola spp.	90 (15)	95 (19)	98 (7)	97 (7)	100 (6)	81 (3)

MSM = Metsulfuron-methyl ; IPU = Isoproturon ; CMPP = Mecoprop

TABLE 5. Weeds controlled in winter cereals with S-23121 at 10 g a.i./ha early post-emergence in France, the UK and West Germany.

% Control	Weed species (Number of trials)	
90 - 100	Adonis aestivalis (2)	Lepidium campestre (1)
	Alchemilla spp. (1)	Raphanus raphanistrum (3)
	Atriplex patula (1)	Sinapis arvensis (1)
	Capsella bursa-pastoris (4)	Stellaria media (24)
	Cardaria draba (1)	Veronica agrestis (1)
	Geranium spp. (1)	Veronica persica (5)
	Lamium amplexicaule (2)	Vicia hirsuta (1)
	Lamium purpureum (4)	Viola arvensis (5)
	Legousia speculum-veneris (6)	Viola tricolor (10)
80 - 89	Galium aparine (17)	Veronica hederifolia (20)
	Ranunculus sardous (1)	
60 - 79	Aphanes arvensis (9)	Myosotis arvensis (4)
	Matricaria chamomilla (19)	Papaver rhoeas (12)
0 - 59	Alopecurus myosuroides (1)	Lolium multiflorum (1)
	Apera spica-venti (7)	Lolium rigidum (1)
	Avena spp. (3)	Poa annua (5)

Efficacy on some weeds is improved by combining S-23121 with other herbicides such as isoproturon or mecoprop. In particular, S-23121 + isoproturon controlled a wide spectrum of broad-leaved and grass weeds.

S-23121 was ineffective on Stellaria media and Matricaria chamomilla in post-emergence trials in West Germany (Table 4). Its efficacy appears to depend on the growth stage of weeds at the time of treatment. Applications in West Germany were made later than in France, which is probably why the efficacy was inadequate against certain weeds. Effective control of these species was accomplished with combinations of S-23121 with isoproturon, mecoprop or metsulfuron-methyl. All these treatments were superior to dichlorprop + ioxynil.

Safety of wheat and barley with S-23121 was excellent at 10-20 g a.i./ha. Occasionally, brown and bleached flecks appeared on the treated crop leaves 1-4 weeks after foliar applications, but plants rapidly recovered, and at final assessment, the treated plots were not visibly different from the untreated.

Results of early post-emergence field trials in France, the UK and West Germany (Table 5), demonstrated that S-23121 at 10 g a.i./ha controls many important broad-leaved weeds, but only suppresses grass weeds.

DISCUSSION

S-23121 is a new herbicide which is highly effective against a wide range of broad-leaved weeds in cereal crops. In particular, it offers excellent control of troublesome weeds such as Galium aparine, Veronica spp. and Viola spp. Rates of 10-20 g a.i./ha are recommended for pre-emergence control in the UK, and 10-20 g a.i./ha for post-emergence control in France and West Germany.

For broader spectrum weed control, S-23121 can be used as a mixture partner with for example isoproturon, mecoprop or metsulfuron-methyl. Such combinations will control most annual broad-leaved and annual grass weeds which are important in cereal crops in Europe and other countries

ACKNOWLEDGEMENTS

We gratefully acknowledge and appreciate the assistance given by those companies which are developing S-23121 with us. Our special thanks are expressed to those collaborating companies in Europe who have supplied their evaluation results on the compound.

REFERENCE

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FLUOROGLYCOFEN-ETHYL: A NEW SELECTIVE HERBICIDE FOR BROAD-LEAVED WEEDS IN CEREALS

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ABSTRACT

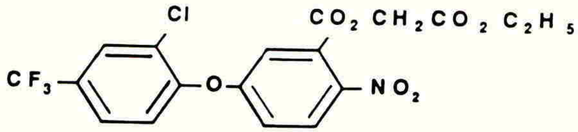
Fluoroglycofen-ethyl is a new selective herbicide developed by the Rohm and Haas Company for post-emergence use in cereals. It has contact activity on a wide range of broad-leaved weeds, especially on some which are difficult to control such as Galium aparine and Viola tricolor. These properties make fluoroglycofen-ethyl an effective partner for other post-emergence compounds. The use rate on cereals is low, between 30 and 40 g a.i./ha.

INTRODUCTION

Fluoroglycofen-ethyl (RH-0265, trademark 'Compete') is a new diphenyl ether herbicide being developed by the Rohm and Haas Company as a post-emergence herbicide for broad-leaved weeds in cereals. It has been tested extensively alone and in combination with other herbicides. The paper describes the main properties of the compound.

CHEMICAL AND PHYSICAL PROPERTIES

Structural formula:



Chemical name (IUPAC): ethyl *O*-[5-(2-chloro-α,α,α-trifluro-*p*-tolyloxy)-2-nitrobenzoyl]glycolate

Physical properties of the pure chemical

Appearance:	solid, dark brown to tan
Odour:	musky
Solubility in water:	less than 1 ppm at 20°C
in organic solvent:	more than 10% at 20°C
Stability:	relatively resistant to decomposition by UV irradiation. Aqueous solutions quickly decompose when irradiated by UV light.

TOXICOLOGY

Toxicological data shown below refer to technical material.

Acute oral LD50 rat	:	1500 mg/kg
Acute dermal LD50 rabbit	:	>5000 mg/kg
Eye irritation rabbit	:	slight
Skin irritation rabbit	:	slight
Teratogenicity	:	no effect on rats and rabbits observed in various tests in-vivo and in-vitro.

ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY

Mallard dietary LC50	:	>5000 ppm a.i.
Quail dietary LC50	:	>5000 ppm a.i.
Bluegill LC50	:	1.6 mg a.i./litre (96 hours)
Trout LC50	:	23 mg a.i./litre (96 hours)
Daphnia LC50	:	30 mg a.i./litre (48 hours)
Honeybee Contact LD50	:	>100 microgram/bee

Fluoroglycofen-ethyl degrades rapidly in water and the potential for bioaccumulation is low.

MODE OF ACTION

Fluoroglycofen-ethyl appears to act similarly to other p-nitro diphenyl ether herbicides such as acifluorfen-sodium and oxyfluorfen. Once it is absorbed by the plant, the chemical becomes effective only under conditions of light. It acts by causing an accumulation of tetrapyrroles reacting with molecular oxygen to produce compounds toxic to the cells. This process leads to the loss of membrane integrity and subsequent leakage of cell content.

BIOLOGICAL PERFORMANCE

A relatively low use rate of fluoroglycofen-ethyl is required for post-emergence broad-leaved weed control. It has also some activity when applied to the soil, pre-emergence on the sensitive dicotyledonous plants, but only at rates two to ten times higher than the post-emergence rate. It is not effective for control of grass or perennial weeds.

MATERIALS AND METHODS

Biological results reported in this paper were obtained from field work carried out in many European countries: France, United Kingdom, Germany, Switzerland, Netherlands, Belgium and Italy. Trials were conducted at sites with moderate to high infestations of indigenous weed species. The trial design was randomised block with 4 replicates, and plots size was 20 to 40 m^2. A knapsack sprayer was used for herbicide application at volumes of 200 to 400 litres/ha at 300 kPa pressure.

Trials were conducted with a 5% wettable powder formulation. Visual assessments of weed control were made between 30 and 45 days after treatment.

RESULTS

Cereal tolerance

Fluoroglycofen-ethyl can be applied post-emergence at any stage between 3 leaves and stem elongation to winter wheat and winter barley. Under some conditions, it can cause injury to cereals in the form of temporary small white spots on the leaves. This injury disappears within a few weeks after application. Results for cereal tolerance to fluoroglycofen-ethyl applied at two rates at mid-tillering compared with the standard herbicide treatment are shown in Table 1.

TABLE 1. Winter wheat tolerance assessed at 7 to 15 DAT.

Material	Rate	Number of trials (% injury range)			
	g a.i./ha	0-5%	6-10%	11-20%	Total
fluoroglycofen-ethyl	30	20	2		22
	60	14	3	2	19
CMPP + ioxynil (EC)	1080+360	21	1		22

Post-emergence weed control

Fluoroglycofen-ethyl acts rapidly and the effect is relatively independent of temperature. It is very effective on common species such as *Veronica spp*. but also on some key weeds which are generally difficult to control such as *Galium aparine* and *Viola tricolor*. The results in Table 2 show the weed spectrum and the level of activity on weeds which were at the 5-10 cm stage.

TABLE 2. Percentage control of weed species in cereals with fluoroglycofen-ethyl post-emergence at 30 g a.i./ha, number of trials between 1983 and 1989.

Weed species	Number of trials (% Control range) 100-90%	90-80%	80-70%	70-50%	Total
Galium aparine	20	15	5		40
Veronica hederaefolia	18	7	8	7	40
Viola tricolor	12	1	1	6	20
Matricaria sp.	4	3	2	10	19
Veronica persica	6	7			13
Lamium sp.	3	6			9
Capsella bursa-pastoris				8	8
Aphanes arvensis				8	8
Papaver rhoeas		3	3	1	7
Stellaria media	1	1		5	7
Lapsana communis	2		2	1	5
Anthemis arvensis	2	1	1		4
Sinapis arvensis			4		4
Fumaria officinalis	2				2
Galeopsis tetrahit	2				2
Myosotis arvensis	2				2
Polygonum aviculare	1		1		2

As shown in Table 3, small weeds are more sensitive to fluoroglycofen-ethyl than larger ones and this is especially true of less sensitive species, for example, Matricaria.

TABLE 3. Percentage control of weeds at two different stages with fluroglycofen-ethyl applied early and late post-emergence at 30 g a.i./ha. Number of trials are shown in parentheses.

Weed species	% Control early 2-5 cm high	late >10 cm high
Galium aparine	91 (9)	88 (5)
Veronica hederaefolia	94 (11)	94 (8)
Viola tricolor	90 (9)	81 (6)
Matricaria sp.	88 (3)	48 (4)

The percentage control of weed species with a range of doses of fluoroglycofen-ethyl is shown in table 4.

TABLE 4. Dose effect of fluoroglycofen-ethyl applied post-emergence at an early stage of the weeds (5-10 cm) and number of trials.

Weed species	% Control (rates in g a.i./ha)				No. of trials
	20	30	40	60	
Galium aparine	85	91	95	97	11
Veronica hederaefolia	87	92	94	97	9
Veronica persica	92	96	99	99	2
Viola tricolor	95	97	98	99	10
Papaver rhoeas	55	79	85	84	5
Matricaria spp.	59	70	89	-	5
Stellaria media	34	44	59	-	7

Because of its good activity on some of the most difficult weeds to control in cereals, fluoroglycofen-ethyl is a very interesting partner for other grass and/or herbicides for broad-leaved weeds currently used. Several combinations, with mecoprop and sulfonylureas are under development.

CONCLUSION

Fluoroglycofen-ethyl is a diphenyl ether herbicide which is effective at rates of 30 to 40 g a.i./ha for the control of several problem broad-leaved weeds in cereals. Cereal crops are tolerant although temporary leaf spotting can occur under some conditions. These characteristics make it ideal for mixture with established cereal herbicides which control a complementary weed spectrum, particularly mecoprop and some sulfonylureas.

ACKNOWLEDGEMENT

We thank the research and development team who have given excellent support to fluoroglycofen-ethyl projects in Europe.

AKH-7088: A NOVEL DIPHENYL ETHER HERBICIDE

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ABSTRACT

Methyl (EZ)-1-[5-(2-chloro-α,α,α-trifluoro-p-tolyloxy)-2-nitrophenyl]-2-methoxyethylideneamino-oxyacetate (code number AKH-7088) is currently under development as a post-emergence herbicide. In soybeans it selectively controls a wide spectrum of broad-leaved weeds including problem species such as *Abutilon theophrasti*, *Xanthium strumarium* and *Datura stramonium* at post-emergence application rates of 0.1-0.2 kg a.i./ha. The *E* and *Z* geometrical isomers of AKH-7088 have been separately synthesised, and greenhouse testing has shown no significant difference between the herbicidal effects of the two isomers on broad-leaved weeds. Mixtures of the two isomers in various proportions exhibit practically the same biological effects as those of each isomer alone. Soybeans show excellent tolerance to the isomers and their mixtures.

INTRODUCTION

Several 2-chloro-4-(trifluoromethyl)-3'-substituted-4'-nitrodiphenyl ether herbicides demonstrate good pre- and post-emergence activity against a wide spectrum of grasses and broad-leaved weeds, but are highly phytotoxic to crops. One exception is sodium 5- [2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoate (common name acifluorfen-sodium) which has been developed as a selective post-emergence herbicide against broad-leaved weeds in soybeans (Johnson *et al*., 1978).

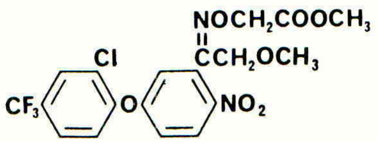
Intensive studies were carried out by the Asahi Chemical Industry Co. Ltd. to develop a novel diphenyl ether with crop selectivity and high herbicidal activity, by means of systematic synthesis and investigation of many compounds with various substituent groups at the 3'- position. Diphenyl ether derivatives having oxime substituent groups were found to exhibit increased herbicidal activity and soybean selectivity (Hayashi and Misumi, 1987). AKH-7088, discovered in 1984, was selected by from these by structural optimisation based on the structure/activity relationships of many synthesised derivatives (Hayashi, 1989).

We report the physical and chemical properties, and preliminary investigations on toxicology of AKH-7088, and the post-emergence herbicidal activity of AKH-7088 and its isomers.

CHEMICAL AND PHYSICAL PROPERTIES

Structure EZ:

E isomer



Z isomer

Chemical name IUPAC:	methyl (EZ)-1-[5-(2-chloro-α,α,α-trifluoro-p-tolyloxy)-2-nitrophenyl]-2-methoxyethylideneamino-oxyacetate
Code number:	AKH-7088
Common name:	none given yet
Empirical formula:	$C_{19}H_{16}ClF_3N_2O_7$
Molecular weight:	476.80
Appearance:	colorless crystalline solid
Melting point:	57.7-58.1°C
Volatility:	extremely low
Solubility:	water 1 mg/l (20°C) dichloromethane >50% (20°C) toluene 15% (20°C)

TOXICOLOGY

The acute toxicity of AKH-7088 (technical material) is summarised here and additional work is in progress.

Acute mammalian toxicity of AKH-7088 (technical material)

Acute oral (albino rate, male and female) LD50:	5000 mg/kg
Acute dermal (albino rate, male and female) LD50:	2000 mg/kg
Skin irritation (rabbit, male):	mild
Eye irritation (rabbit, male):	minimal

Mutagenicity

AKH-7088 is non-mutagenic as determined by the Ames Test.

MATERIALS AND METHODS

Greenhouse testing

The separate E and Z isomers of AKH-7088, their mixtures in various proportions and the technical compound AKH-7088 were evaluated for post-emergence herbicidal activity in a greenhouse. Each test formulation, an emulsifiable concentrate, was prepared by mixing the test compound, a surfactant (Sorpol 3005X), xylene and cyclohexanone in a ratio of 10:10:40:40 by weight.

Seeds of 10 test species were planted in pots with a surface area of $0.24m^2$ filled with sterilised soil. The test broad-leaved species were *Polygonum lapathifolium*, *Cassia obtusifolia*, *Abutilon theophrasti*, *Solanum nigrum*, *Ipomoea* spp., *Amaranthus retroflexus*, *Sida spinosa* and *Xanthium strumarium*; the grass was *Digitaria ciliaris* and the crop was soybean cv. Williams.

The test formulations were applied post-emergence in 200 l/ha volume of water at dose rates of 0.035, 0.07, 0.14 and 0.28 kg a.i./ha when the soybeans were at 1.5 to 2 trifoliate leaf stage and the weeds were at the 2 to 6 leaf stage. The test was replicated three times. Weed control was assessed visually 14 days after treatment as percentage growth reduction of treated compared with untreated plants. Percentage crop injury was determined in the same manner 21 days after treatment.

Field testing

Field trials reported in this paper were conducted in Yokohama, Kanagawa, Japan during the 1985 and 1986 cropping seasons. AKH-7088 was applied post-emergence in randomised complete block tests with 3 replications and plot sizes ranging from 1 to 4 m^2. The weeds were those included in the greenhouse tests plus *Chenopodium album*, *Datura stramonium* and *Sesbania exaltata* and the crops were soybeans, corn (*Zea mays*), rice and wheat. Rates of 0.05, 0.1, 0.2 and 0.4 kg a.i./ha were applied in spray volumes of 200 to 1000 l/ha. At the time of application the weeds were at 2 to 10 leaf stage and 3 to 20 cm high, and the crops were at 1 to 2 leaf (soybeans at 1-2 trifoliate leaf) stage and 13 to 16 cm high. Weed control and crop tolerance assessments were made by visual estimation of percentage phytotoxicity 14 or 21 days after treatment, respectively.

Similar tests were also carried out with pre-emergence applications of AKH-7088 at dosages of 0.2 - 0.8 kg a.i./ha..

RESULTS AND DISCUSSION

Weed control

Greenhouse and field tests demonstrated that AKH-7088 controlled a wide range of economically important weed species (Table 1). Table 2 shows that *Abutilon theophrasti*, *Polygonum lapathifolium*, *Datura stramonium* and *Sida spinosa* were particularly sensitive to AKH-7088, and were controlled by a dosage as low as 0.05 kg a.i./ha. *Xanthium strumarium* and *Sesbania exaltata* were well controlled at 0.1-0.2 kg a.i./ha. *Chenopodium album* was slightly less sensitive and *Ipomoea* spp. and *Cassia obtusifolia* were only controlled at high dose rates. Digitaria ciliaris was only partially suppressed (Table 2). AKH-7088 is clearly a fast-acting contact herbicide with maximum effects seen 3 to 10 days after application.

AKH-7088 was found to be less active when applied pre-emergence and doses higher than 0.5 kg a.i./ha were required for effective control.

TABLE 1. Activity of AKH-7088 on weed species.

Good - excellent control	Inconsistent control	Limited suppression
Abutilon theophrasti	Chenopodium album	Digitaria ciliaris
Polygonum lapathifolium	Ipomoea spp.	
Datura stramonium	Cassia obtusifolia	
Sida spinosa		
Xanthium strumarium		
Sesbania exaltata		
Amaranthus retroflexus		

TABLE 2. Post-emergence herbicidal activity and soybean selectivity of AKH-7088 (technical material) in field trials Yokohama, Japan.

		% Phytotoxicity			
Weed species	kg a.i./ha	0.40	0.20	0.10	0.05
Abutilon theophrasti		100	100	100	100
Amaranthus retroflexus		100	100	100	99
Cassia obtusifolia		78	68	51	40
Chenopodium ablum		93	81	73	72
Datura stramonium		100	100	97	95
Digitaria ciliaris		55	40	27	14
Ipomoea spp.		78	65	40	24
Polygonum lapathifolium		100	100	98	97
Sesbania exaltatus		100	100	90	88
Sida spinosa		100	99	96	93
Xanthium strumarium		96	92	88	65
Soybean		18	8	2	0

The results of greenhouse trials indicate that, against all weeds tested, the herbicidal activities of the E isomer alone, the Z isomer alone, the mixture of both in various ratios, and technical compound AKH-7088 are virtually the same (Table 3).

TABLE 3. Post-emergence herbicidal activity and soybean selectivity for technical AKH-7088, its geometrical isomers, and mixtures of isomers in various ratios (greenhouse tests).

E:Z ratio	kg a.i./ha	% Phytotoxicity DIGCI	POLLA	CASOB	ABUTH	SOLNI	IPO ss	AMARE	SIDSP	XANST	SOY
	0.28	40	100	97	100	100	95	100	97	100	30
100:0	0.14	30	98	60	100	80	80	97	90	99	25
	0.07	25	85	55	100	75	60	95	70	85	15
	0.035	20	80	30	100	70	60	90	60	65	10
	0.28	35	100	98	100	100	85	100	90	95	30
75:25	0.14	35	98	75	100	98	80	100	80	90	15
	0.07	35	85	55	100	95	70	100	75	80	15
	0.035	35	80	40	100	80	60	96	70	70	10
	0.28	35	100	100	100	100	98	100	95	100	35
50:50	0.14	30	98	85	100	100	75	100	90	95	20
	0.07	25	85	65	100	90	60	95	80	75	15
	0.035	25	70	55	100	75	50	85	65	60	9
	0.28	30	100	90	100	100	90	99	92	100	30
25:75	0.14	30	88	78	100	95	85	98	80	97	20
	0.07	30	80	60	100	90	60	90	80	75	15
	0.035	20	75	55	95	70	60	85	60	55	7
	0.28	30	100	90	100	99	98	100	85	100	25
0:100	0.14	25	95	85	100	95	90	100	78	90	20
	0.07	20	90	65	100	95	85	100	75	85	10
	0.035	5	80	60	98	85	60	90	65	80	10
tech.	0.28	35	100	95	100	100	90	100	95	100	30
AKH-	0.14	35	98	80	100	98	85	100	85	95	15
7088	0.07	30	85	65	100	95	70	95	80	80	15
	0.035	30	75	55	100	80	60	85	65	70	7

DIGCI = *Digitaria ciliaris*
POLLA = *Polygonum lapathifolium*
CASOB = *Cassia obtusifolia*
ABUTH = *Abutilon theophrasti*
SOLNI = *Solanum nigrum*
IPO ss = *Ipomoea* spp.
AMARE = *Amaranthus retroflexus*
SIDSP = *Sida spinosa*
XANST = *Xanthium strumarium*
SOY = Soybean

Crop tolerance

Soybeans at all growth stages were highly tolerant to AKH-7088 (Table 2) and injury which was observed was localised and temporary. Symptoms were leaf crinkling and speckling soon after application, particularly on the youngest leaves, but these disappeared rapidly. Soybeans were also tolerant of pre-emergence applications (data not presented). Selectivity in soybeans for the E isomer alone, the Z isomer alone, the mixture of both and technical compound AKH-7088 are the same (Table 3).

Corn, rice and wheat were also tolerant of pre- and post-emergence applications of AKH-7088 (data not presented).

CONCLUSIONS

AKH-7088 is a promising new diphenyl ether herbicide with foliar activity on a wide range of broad-leaved weeds. In particular, AKH-7088 shows excellent control of weeds which are often a problem in soybeans such as *Abutilon theophrasti*, *Xanthium strumarium* and *Datura stramonium*. The technical compound AKH-7088 is a mixture of E and Z isomers. The activities on weeds and on soybeans of the E isomer alone, their mixture in various ratios, and the technical compound AKH-7088 were virtually the same. Applications can be made post-emergence with excellent selectivity in soybeans and other important crops such as corn, rice and wheat.

ACKNOWLEDGEMENTS

The authors wish to thank Y. Yoshioka and T. Hoshino for assistance with synthesis of these compounds.

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RH-0898: A NEW SELECTIVE POST-EMERGENCE HERBICIDE FOR GRASS WEED CONTROL

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ABSTRACT

RH-0898, (RS)-2-[2-{4-(3,5-dichloro-2-pyridyloxy)phenoxy} propionyl]isoxazolidine, is a new post-emergence grass herbicide selective in rice, wheat and broad-leaved crops. Field results to date have indicated excellent control of *Echinochloa* spp., *Brachiaria* spp., *Leptochloa* spp., and *Digitaria* spp., in rice and *Avena* spp., *Setaria* spp., and *Alopecurus* spp., in spring and durum wheat at dosages as low as 60-90 g a.i./ha. Grass control is most effective when RH-0898 is applied at the 2-5 leaf stage. Uptake is mainly through the foliage and requires the addition of an emulsified oil concentrate at 0.5-2% v/v of carrier volume to aid penetration.

INTRODUCTION

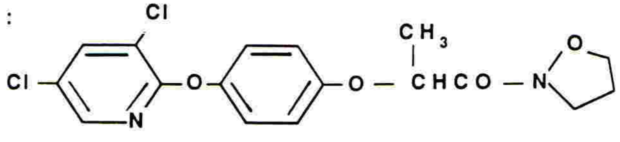
RH-0898 is a new post-emergence grass herbicide discovered by Hokko Chemical Industry Limited. RH-0898, also coded as HOK-1566, is being jointly developed with the Rohm and Haas Company for use in direct seeded rice, spring wheat, durum wheat, and broad-leaved crops such as soybean, cotton, sugar beet, rape and vegetables. RH-0898 provides excellent post-emergence control at low use rates of economically important grass weeds such as *Alopecurus myosuroides*, *Avena fatua*, *Brachiaria* spp., *Digitaria* spp., *Echinochloa* spp., *Leptochloa* spp., and *Setaria viridis*. This paper describes the chemical and physical properties of RH-0898 and presents some data from a greenhouse and world-wide field testing programme.

CHEMICAL AND PHYSICAL PROPERTIES

Common name (BSI) : isoxapyrifop

Chemical name (IUPAC) : (RS)-2-[2-{4-(3,5-dichloro-2-pyridyloxy) phenoxy}propionyl]isoxazolidine.

Chemical formula :



Empirical formula	:	$C_{17}H_{16}Cl_2N_2O_4$
Molecular weight	:	383.2
Appearance	:	white crystalline solid
Melting Point	:	121-122°C
Solubility in water	:	9.8 mg/l at 25°C
n-octanol/water coefficient	:	log P=3.68

FORMULATION

RH-0898 is formulated as a 50% dispersable granular (DG) and a 22% flowable formulation.

TOXICOLOGY OF TECHNICAL MATERIAL

Acute mammalian toxicity	LD50 oral (female rat)	: 1400 mg/kg
	LD50 oral (male rat)	: 500 mg/kg
	LD50 dermal (rat)	: >5000 mg/kg
	LD50 dermal (rabbit)	: >2000 mg/kg
Acute fish toxicity	Bluegill LC50	: 1.4 mg/l after 96 h
	Rainbow Trout LC50	: 1.3 mg/l after 96 h
	Daphnia LD50	: >10.1 mg/l after 6 h
Acute avian toxicity	Japanese quail LD50	: >5000 mg/kg
Skin and eye irritation rabbit:	Non-irritating to skin and slightly irritating to the eye.	
Mutagenicity (5 different tests):	Non-mutagenic.	
Teratogenicity (rat and rabbit):	Non-teratogenic 2-week range-finding studies.	
Chronic testing (mouse):	"no effect" level 0.02 mg/kg/day after 78 weeks of feeding.	

ENVIRONMENTAL STUDIES

RH-0898 degrades rapidly in crops and soil to a pyridyloxy phenoxy propionic acid metabolite, which in turn degrades more slowly. The half-life of RH-0898 and its pyridyloxy phenoxy propionic acid metabolite in aerobic laboratory studies are 1-4 d and 30-90 d respectively.

The classification for soil mobility in Helling's thinlayer chromatography test is immobile to low mobility for RH-0898 and low to moderately mobile for the pyridyloxy phenoxy propionic acid metabolite. Both classifications depend on soil type.

HERBICIDE ACTIVITY

RH-0898 is most effective when annual grasses are actively growing at the 2-6 leaf stage. Uptake occurs mainly through the foliage and penetration is aided by the addition of 0.5-2% v/v crop oil concentrate, such as a petroleum oil or seed oil containing 13-17% emulsifier. RH-0898 is systemic and inhibits the growth of meristematic tissue in susceptible weed species. Herbicidal activity is dependent on growth rate and becomes apparent within 1 to 3 weeks following application. Chlorosis and necrosis develops first in the youngest tissue, and increases until plant death occurs 3 to 6 weeks after application.

MATERIALS AND METHODS

Greenhouse screening of RH-0898 for post-emergence activity was conducted on 12 species of grass weeds and 7 crops. Seeds were germinated in flats or pots and allowed to grow to the 2-4 leaf stage. All plants were watered by sub-irrigation. RH-0898 (technical material) was dissolved in acetone and sprayed in a carrier volume equivalent to 454 l/ha. Three weeks after application the treatments were evaluated for activity.

Field trials were established from 1985-1988 to evaluate efficacy on direct seeded rice in the US, Brazil and Colombia and on spring wheat in Canada, US and Australia. All trials were carried out in natural weed infestations in commercial crops. Experiments were of complete randomized design with 3-4 replications and plot sizes ranging from 10-120 m^2. Treatments were applied with a hand-held boom sprayer at 90-180 l/ha volume containing from 0.5-1% crop oil concentrate. Weed control and crop tolerance were assessed visually in greenhouse and field trials on a 0-100% scale.

RESULTS AND DISCUSSIONS

Greenhouse Results

Greenhouse tests demonstrated activity of RH-0898 at low rates on a wide range of economically important grass weeds (Table 1). Two important species not controlled are *Bromus tectorum* and *Cyperus esculentus*.

The tolerance of cotton, soybean, sugar beet and spring wheat to RH-0899 is shown in Table 1. Rice is tolerant at rates that control it's most important grass weed *Echinochloa crus-galli*.

TABLE 1. Greenhouse tests: post-emergence activity of RH-0898 on 12 economically important grass weed species (% control), and on crops (% phytotoxicity).

Species	Rate of RH-0898 g a.i./ha 30	60	120	250	500
Grass weed	% Control (No. of tests)				
Alopecurus myosuroides	37 (8)	65 (8)	89 (8)	95 (5)	100 (2)
Avena fatua	62 (5)	60 (8)	90 (6)	95 (6)	100 (4)
Brachiaria platyphylla	67 (9)	76 (12)	91 (12)	88 (10)	99 (6)
Bromus tectorum	0 (7)	1 (8)	4 (7)	0 (5)	0 (1)
Cyperus esculentus	-	0 (3)	0 (1)	0 (3)	0 (1)
Digitaria sanguinalis	48 (9)	65 (9)	81 (10)	83 (7)	93 (4)
Echinochloa crus-galli	94 (9)	96 (12)	99 (16)	100 (17)	100 (11)
Leptochloa spp.	20 (2)	58 (2)	73 (4)	99 (4)	99 (4)
Lolium muliforum	34 (9)	53 (9)	70 (9)	89 (6)	98 (3)
Phalaris minor	53 (6)	75 (9)	86 (7)	93 (8)	99 (3)
Setaria viridis	50 (11)	63 (14)	89 (13)	91 (12)	96 (6)
*Sorghum halepense**	-	45 (3)	87 (3)	86 (5)	99 (3)
Crop	% Phytotoxicity (No. of tests)				
Cotton	2 (1)	0 (4)	3 (2)	13 (4)	0 (2)
Maize	80 (1)	93 (4)	100 (2)	93 (3)	100 (1)
Rice	11 (5)	21 (8)	41 (11)	45 (12)	65 (9)
Soybean	0 (2)	1 (5)	0 (3)	4 (5)	7 (3)
Spring barley	-	-	10 (1)	15 (1)	20 (1)
Spring wheat	6 (5)	6 (8)	12 (8)	11 (10)	9 (7)
Sugar beet	0 (1)	0 (4)	0 (2)	0 (4)	0 (2)

*Seedling

Field results

Field trials in the US, Brazil and Colombia have demonstrated excellent tolerance in direct seeded rice with RH-0898 applications upto 200 g a.i./ha. Data from these countries show adequate selectivity and control of *Echinochloa* spp., *Brachiaria* and *Leptochloa* spp., from 75-150 g a.i./ha plus 0.5 to 1% v/v crop oil concentrate. Control of grasses early at the 2-4 leaf stage can be achieved at rates as low as 75 g a.i./ha while larger 4-6 leaf grasses require higher 100 g a.i./ha rates. RH-0898 at 75-100 g a.i./ha is more effective for control of *Leptochloa* spp., and 4-6 leaf *Echinochloa crus-galli* than the standard propanil treatment (Table 2).

Yields of three rice varieties popular in the mid-south of the US were not reduced with RH-0898 applications at rates as high as 200 g a.i./ha in trials conducted under weed free conditions to eliminate the influence of weed competition on yield (Table 3).

TABLE 2. Percentage control of Echinochloa crus-galli (4 trials), Brachiaria (4 trials) and Leptochloa spp. (2 trials) a. at 2-4 leaf stage and b. 4-6 leaf stage with RH-0898 in direct seeded rice (US, 1988).

Treatment	Rate g a.i./ha	% weed control: Echinochloa	Brachiaria	Leptochloa
a. Weeds 2-4 leaf				
RH-0898 + COC	75	90	76	96
	100	90	85	98
	150	91	89	99
Propanil	3000	88	89	61
b. Weeds 4-6 leaf				
RH-0898 + COC	75	88	82	97
	100	91	85	99
	150	94	85	99
Propanil	5000	53	93	38

COC = Crop oil concentrate at 0.62% v/v

TABLE 3. Yields of rice varieties treated with RH-0898 under weed free conditions.

Treatment	Rate g a.i./ha	Rice yield t/ha: Mars	New Bonnet	Lammont
RH-0898 + COC	100	4.17 abc	5.05 a	5.54 a
	150	4.41 ab	5.05 a	5.49 a
	200	4.56 a	5.15 a	6.28 a
Propanil	3000	3.92 bc	5.20 a	6.03 a

COC = Crop oil concentrate at 0.62% v/v

Field trials in Canada, US and Australia have demonstrated tolerance of spring wheat to RH-0898 at rates up to 150 g a.i./ha when applied at the 2-5 leaf stage. Data also show excellent control of Avena spp. and Lolium rigidum as well as suppression of Setaria viridis at low 75 g a.i./ha rates, (Tables 4 and 5).

TABLE 4. Percentage control of *Avena fatua* and *Setaria viridis* with RH-0898 and yield of spring wheat, mean of 3 trials (US, 1988).

Treatment	Rate g a.i./ha	Weed control Avena	Setaria	Yield t/ha
RH-0898 + COC	75	96	61	3.46
	100	96	67	3.24
	150	92	76	3.38
Dichlofop-methyl + COC	750	83	57	3.17
Control		0	0	1.94

COC = Crop oil concentrate at 1.2% v/v

TABLE 5. RH-0898 control of *Avena* spp. and *Lolium ridigum* in spring wheat, mean of 5 trials (1987-1988, Australia).

Treatment	Rate g a.i./ha	Weed control Avena	Lolium	Yield t/ha
RH-0898 + COC	75	95	92	1.34
	100	97	94	1.40
	150	98	96	1.39
Dichlofop-methly + COC	530-750	98	98	1.46
Control		0	0	0.65

COC = Crop oil concentrate at 1.5% v/v

Compatibility with herbicide for broad-leaved weeds

Tank-mixes of RH-0898 and herbicides for broad-leaved weeds have been tested on rice and spring wheat in both the greenhouse and the field. There was little or no reduction in activity on grasses when RH-0898 is mixed with some sulfonylureas, bromoxynil or triclopyr. However, tank-mixes with 2,4-D, MCPA, MCPP and propanil are antagonistic and reduce grass control to unacceptable levels.

CONCLUSION

RH-0898 is a new highly active post-emergence grass herbicide being developed for rice and spring wheat. Toxicological and environmental tests completed to date are favourable. With good selectivity, low use rates and a favourable spectrum of activity, RH-0898 has demonstrated considerable promise as a selective post-emergence grass herbicide.

UBI C4874, A NEW POSTEMERGENCE HERBICIDE FOR CONTROL OF ANNUAL AND PERENNIAL GRASSES

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ABSTRACT

UBI C4874, (±)-tetrahydrofurfuryl (R)-2-[4-(6-chloroquinoxalin-2-yloxy)-phenoxy] propanoate, is a very active new herbicide for control of annual grasses such as *Avena fatua* and *Alopecurus myosuroides* as well as perennial grasses such as *Sorghum halepense* and *Elymus repens*. Dicotyledonous crops such as potatoes, flax, sugar beet, rape, peas, soybeans and cotton are tolerant of UBI C4874. The application rate of 30-150 g a.i./ha varies with grass species, age of grass and general growing conditions. Young actively growing annuals generally require the lowest and older perennials the highest application rate, especially when growing under stress conditions. An adjuvant such as a crop oil concentrate (83% mineral oil with 17% surfactant) added to the UBI C4874 spray solution improves activity under adverse conditions.

INTRODUCTION

Both annual and perennial grasses are competitive in broad-leaved crops and few would argue against the need to control them. Existing commercial pre-emergence herbicides are generally effective in controlling annual grasses but are adversely influenced by extremely dry or wet soils, must generally be applied over an entire field as an insurance treatment and require relatively high rates. Perennial grasses are not well controlled by pre-emergence herbicides but foliar suppression can be achieved with some post-emergence graminicides. UBI C4874 is an excellent new post-emergence graminicide which will control both annual and perennial grasses in dicotyledonous crops such as potatoes, flax, sugar beet, rape, soybeans and cotton.

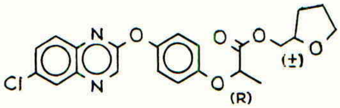
This paper presents chemical, physical and toxicological properties of UBI C4874 in addition to efficacy data.

2—8

CHEMICAL AND PHYSICAL PROPERTIES

Chemical name (IUPAC): (±)-tetrahydrofurfuryl (R)-2-[4-(6-chloro quinoxalin-2-yloxy) phenoxy] propanoate

Structure:



Empirical formula: $C_{22}H_{21}N_2ClO_5$

Molecular weight: 428.861

Physical form: Amber viscous liquid

Density at 24°C: 1340 ± 40 kg/m^3

Odour: Slight

Solubility at 25°C:

Toluene	65.2 g/100 ml
Hexane	1.2 g/100 ml
Methanol	6.4 g/100 ml
Water	0.4 mg/100 ml

TOXICOLOGY

	Technical Material	E.C. 120 g a.i./l
Acute toxicity:		
Oral LD50 rat	1140 mg/kg	3100 mg/kg
Oral LD50 bobwhite quail	>2150 mg/kg	--
Oral LC50 Mallard duck	>5000 ppm	--
Oral LC50 bobwhite quail	>5000 ppm	--
Dermal LD50, rabbit	>2000 mg/kg	>2000 mg/kg
Irritation:		
Dermal, rabbit	non	non
Eye, rabbit	mild	irritant
Sensitisation:		
Guinea pig	non	non

FORMULATION

Two formulations of UBI C4874 as emulsifiable concentrates are currently available. The first contains 120 g a.i./l and the second, containing 40 g a.i./l is formulated with a non phytotoxic oil.

EFFICACY

Weeds and volunteer crops susceptible to UBI C4874:-

Annual grasses controlled at 30-90 g a.i./ha
Alopecurus myosuroides
Avena fatua
Brachiaria platyphylla
Bromus mollis
Bromus secalinus
Bromus tectorum
Cenchrus spp.
Digitaria spp.
Echinochloa crus-galli
Eleusine indica
Panicum dichotomiflorum
Panicum texanum
Panicum miliaceum
Rottboellia exaltata
Setaria spp.
Sorghum bicolor
Dactyloctenium aegyptium
Echinochloa colonum
Leptochloa sp.
Sorghum bicolor
Triticum aestivum
Hordeum vulgare
Zea mays

Perennial grasses (Foliar Control) at 70 to 150 g a.i./ha
Elymus repens
Cynodon dactylon
Sorghum halepense

Crops known to be tolerant of UBI C4874:-

soybean	canola (rape)	potato
cotton	sugar beet	pea
peanut	linseed and flax	sunflower
dry bean (*Phaseolus*)	alfalfa	

APPLICATION

UBI C4874 performs best when applied to grasses which are actively growing and not under temperature or moisture stress. The spray solution should include a crop oil concentrate at 2 l/ha and a spray volume to give thorough coverage of foliage.

MATERIALS AND METHODS

UBI C4874 was tested in field trials during the past 3 years in USA, Canada, Brazil, Argentina, Spain, UK and Italy. Randomised complete block designs with three or four replicates were used and plot sizes varied from 5-20 m^2. Treatments were applied with small plot sprayers delivering spray volumes of 150 to 500 l/ha. The formulation of UBI C4874 was a 120 g a.i./l emulsifiable concentrate. Herbicide activity and crop tolerance were determined visually by comparison of treated with untreated plots and expressed as percent control or injury (0% = no weed control or crop injury and 100% = total kill).

RESULTS

The following data from 1988 and 1989 trials in Argentina, Canada and the USA illustrate the efficacy of UBI C4874 for annual and perennial grass control (Tables 1 and 2).

TABLE 1. UBI C4874:Percentage Annual Grass Control and Crop Injury, 1988. 1988.

Postemergence treatment	Rate g a.i./ha	Weed % Control	Crop % Injury
1. Canada		S. viridis (46 DAT)	Dry bean
UBI C4874 + Oil	36	75	0
UBI C4874 + Oil	48	91	0
sethoxydim + Oil	258	96	0
2. USA		P. texanum (36 DAT)	Soybean
UBI C4874 + Oil	33	50	0
UBI C4874 + Oil	67	86	0
UBI C4874 + Oil	134	93	0
fluazifop-p-butyl + oil	213	77	0
3. USA		E. crus-galli (13 DAT)	Sugar beet
UBI C4874 + Oil	33	98	0
UBI C4874 + Oil	67	100	0
sethoxydim + Oil*	336	95	0

DAT -days after treatment

1. Spray volume was 250 l/ha, crop oil (Assist) 2 l/ha, applied at 3 tiller stage of grass.
2. Spray volume was 290 l/ha, crop oil (Super Savol) 2.3 l/ha, applied at fully tillered stage of grass.
3. Spray volume was 190 l/ha, crop oil (Super Savol or *Pace) 2.3 l/ha, applied at fully tillered stage of grass.

TABLE 2. UBI C4874: Percentage Foliar Control of Perennial Grasses and Crop Injury, 1988 and 1989.

Postemergence treatment	Rate g a.i./ha	Weed % Control		Crop % Injury
1. Canada 1988		E. repens (49 DAT)		Dry bean
UBI C4874 + Oil	72	90		0
UBI C4874 + Oil	150	95		0
sethoxydim + Oil*	800	55		0
2. USA 1988		C. dactylon (57 DAT)		Pear
UBI C4874 + Oil	67	80		0
UBI C4874 + Oil	134	96		0
glyphosate	2240	92		0
3. Argentina 1989		S. halepense		Sunflower
		(20 DAT)	(90 DAT)	
UBI C4874 + Oil	72	90	94	0
UBI C4874 + Oil	96	98	99	0
quizalofop-ethyl	86	98	97	0

DAT - days after treatment

1. Spray volume was 250 l/ha, crop oil (Assist) 2 l/ha (*4 l/ha), applied at 3-5 leaf stage of grass.
2. Spray volume was 218 l/ha, crop oil (Super Savol) 2.3 l/ha, applied when grass was 5-12 cm tall.
3. Spray volume was 300 l/ha, crop oil (Super Savol) 1 l/ha, applied at 6-7 leaf stage of grass.

DISCUSSION

UBI C4874 effectively controlled both annual and perennial grasses in broad-leaved crops. The required application rates were relatively low in comparison to application rates of established products such as fluazifop-p-butyl, sethoxydim, or glyphosate and similar to those of quizalofop-ethyl.

ACKNOWLEDGEMENTS

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REFERENCES

Bartlett, D.H.; Jessop, C.D.; Shrimpton, D.R. (1989) Grass weed control in UK with UBI C4874 - a new post-emergence herbicide. Brighton Crop Protection Conference - Weeds 1985. (In print)

CGA 184'927+S: A NEW POST-EMERGENCE GRASSKILLER FOR USE IN CEREALS

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ABSTRACT

CGA 184'927+S is a new herbicide/safener combination for the selective control of annual grasses in cereals worldwide. The herbicide CGA 184'927 provides excellent control of a broad spectrum of important grass weeds such as *Alopecurus myosuroides*, *Avena* spp., *Lolium* spp., *Phalaris* spp., *Poa trivialis* and *Setaria* spp. Rates of use vary between 40-80 g a.i./ha. CGA 184'927 shows a high flexibility with regard to growth stages at application (GS 12 to 30/31), and provides consistently high level of grass weed control under different climatic conditions in both intensively and extensively grown cereals.

The safener compound CGA 185'072 fully protects wheat from injury by the herbicide CGA 184'927. This herbicide/safener combination, applied at a 4:1 ratio, provides a wide crop safety margin in wheat.

INTRODUCTION

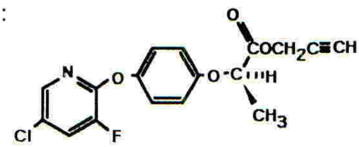
CGA 184'927 is an experimental herbicide, invented and being developed by Ciba-Geigy, Ltd., Basle. CGA 184'927 is applied post-emergence to crop and weeds and provides excellent control of a broad spectrum of annual grasses (for example *Avena* spp. and *Alopecurus* sp.) in small grain cereals. CGA 184'927 applied alone is not fully tolerated by small grain cereals and therefore requires a specific crop safening agent. For this purpose CGA 185'072, an experimental safener compound, is currently being developed by Ciba-Geigy, Ltd., Basle. It has proved to be an effective safener for selective protection of cereal crops from injuries by the herbicide CGA 184'927. This herbicide/safener combination, (CGA 184'927+S) has been tested worldwide over the last three years in cereals. This paper describes the physical and chemical properties of both active ingredients and presents biological results from greenhouse and field trials.

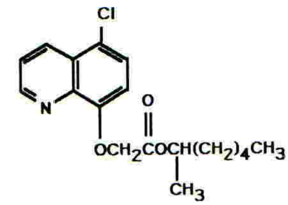
CHEMICAL AND PHYSICAL PROPERTIES

	CGA 184'927	CGA 185'072
Chemical name :	2-propynyl-(R) - 2- [4- (5-chloro-3-fluoro-2-pyridyloxy)-phenoxy]-propionate	5-chlor-8-quinolinoxy-acetic acid-1-methyl-hexyl-ester

		CGA 184'927	CGA 185'072
Molecular formula	:	$C_{17}H_{13}ClFNO_4$	$C_{18}H_{22}ClNO_3$
Molecular weight	:	349.75	335.83

Structural formula :





Characteristics of a.i.

		CGA 184'927	CGA 185'072
Appearance	:	crystalline odourless	crystalline odourless
Melting point	:	59.3°C	69°C
Vapour pressure	:	$5.3x10^{-6}$ Pa at 20°C	$2.5x10^{-6}$ Pa at 20 °C
Solubility	:	2.5 ppm in water at 20°C; soluble in most organic solvents	0.8 ppm in water at 20°C; soluble in most organic solvents

Acute toxicity of a.i.

		CGA 184'927	CGA 185'072
LD50 oral (rat)	:	1829 mg/kg	>2000 mg/kg
LD50 dermal (rat)	:	>2000 mg/kg	>2000 mg/kg
LC50 inhalation (rat 4 h)	:	>2325 mg/m^3	>935 mg/m^3
Irritation (skin, eye) (rabbit)	:	non-irritant	non-irritant

MATERIALS AND METHODS

Trials in the greenhouse were carried out with CGA 184'927 (herbicide) and CGA 185'072 (S = safener) applied separately, where required, or as a formulated mixture. EC-formulations of the compounds alone and of the herbicide/safener combination were used. Applications were made with a water volume of 550 l/ha. Field data with CGA 184'927 + S reported here were from trials carried out in small grain cereals over the last three years. The experimental design was a completely randomised block with three or four replications. The plot size used was 10-20 m^2. The herbicide/safener combination used was an EC formulation containing 100 g/l CGA 184'927 and 25 g/l CGA 185'072. Dose rates indicated in the tables for CGA 184'927 + S refer to g a.i./ha of the herbicide. Applications were made post-emergence with small plot sprayers at spray volumes ranging from 100-500 l/ha. An oil additive was added to the spray solution where appropriate. The standard compounds used were of commercially available formulations. Phytotoxicity to crops and control of grass weeds were assessed visually in comparison with untreated control plots, using a percentage scale of 0 (no effects) to 100 (complete kill of crop or grass weeds). In separate crop tolerance trials on field sites with low or no weed infestation, where CGA 184'927+S was applied at single and double rates, yield data were collected.

RESULTS

Greenhouse trials

CGA 184'927, applied post-emergence, has high herbicidal activity against a large number of monocotyledonous species, while it is tolerated by most broad-leaved species. The following grasses have shown high susceptiblility: *Alopecurus myosuroides, Avena fatua, A. ludoviciana, A. sterilis, Brachiaria plantaginea, Digitaria sanguinalis, Echinochloa crus-galli, Eleusine indica, Lolium multiflorum, L. rigidum, Panicum milleaceum, Phalaris minor, P. paradoxa, Poa trivialis, Setaria glauca, S. viridis, Sorghum bicolor, S. halepense* (seedling). Moderately susceptible are: *Apera spica-venti*, wheat and barley. *Bromus* spp., *Cyperus* spp., *Festuca rubra, Poa annua* and perennial grasses are of low susceptibility. Susceptible plants stop growth within 1-2 days after application. The youngest leaf dies first, while the older leaves may stay green and die later. At sublethal rates young, developing leaves are deformed and leaf unrolling is disturbed.

Since CGA 184'927 alone is not tolerated by monocotyledonous crops, a specific safener (CGA 185'072) was developed. The formulated mixture of CGA 184'927 (herbicide) and CGA 185'072 (safener) in a ratio of 4:1 is selective in wheat at rates exceeding two times the recommended rates of use for weed control. Both herbicide and safener must be applied to the plant foliage to be active as herbicide or as safener (Table 1). Both partners show little activity when applied as a soil drench to the roots.

TABLE 1. Percentage injury from applications of CGA 184'927 (herbicide = H) and CGA 185'072 (safener = S) to shoots and roots. Rates used on wheat: 80/20 g a.i./ha (H/S) and on *Avena fatua*: 40/10 g a.i./ha (H/S).

Treatments to shoots:	HS	H	HS	S	-	S	HS	H	HS
Treatments to roots:	-	S	S	H	HS	HS	H	HS	HS
wheat:	3	54	2	0	2	0	1	62	2
A. fatua:	65	64	54	4	18	12	67	68	59

TABLE 2. Percentage injury from CGA 184'927+S applied post-emergence on wheat and barley (80 g a.i./ha) and *Avena fatua* and *Alopecurus myosuroides* (40 g a.i./ha).

Plant species	% Plant injury					
DAT	2	4	7	11	14	21
Wheat	15	19	5	7	8	8
Barley	37	64	58	39	26	23
A. fatua	40	69	78	89	93	92
A. myosuroides	36	62	74	84	88	96

Under greenhouse conditions the relatively high rate of 80 g a.i./ha of CGA 184'927+S caused some transient symptoms of phytotoxicity in wheat. However, barley was severely injured, especially immediately after application. The plants seemed to recover, but the lower leaves remained damaged. At half this rate (40 g a.i./ha) target grasses showed severe injury initially, and this damage increased rapidly as time progressed (Table 2).

Field trials

CGA 184'927 + S showed excellent control of *Alopecurus myosuroides* and *Avena fatua*, when applied at 50-60 g a.i./ha to intensively grown winter wheat wheat in Europe (Table 3). CGA 184'927 + S controlled weeds independently of growth stage and the compound could be applied without much loss of activity to fully tillered plants (GS 29/30) of either grass species. Against both *Avena fatua* and *Alopecurus myosuroides*, CGA 184'927+S was clearly superior to the standards such as diclofop-methyl and isoproturon. Although *Lolium* spp. and *Poa trivialis* were slightly less susceptible to CGA 184'927+S, the control levels obtained at 60 g a.i./ha were still comparable to isoproturon. The control of *Apera spica-venti* was only moderate and clearly inferior to isoproturon.

TABLE 3. Percentage control with CGA 184'927+S against annual grasses in winter wheat (Europe, 1986-88)

Grass species	(n)	GS at application	CGA 184'927+S g a.i./ha 40	CGA 184'927+S g a.i./ha 50-60	CGA 184'927+S g a.i./ha 80	isoproturon g a.i./ha 1500-2500	diclofop-methyl g a.i./ha 900
A. fatua	(16)	11-25	91	95	96	69	85
	(12)	25-29	92	97	100	-	67
A. myosuroides	(13)	11-25	-	96	99	87	-
	(13)	25-30	-	91	96	71	-
P. trivialis	(3)	21-25	72	92	-	85	-
Lolium spp.	(5)	21-29	65	80	87	74	96
A. spica-venti	(19)	13-25	-	72	77	95	-
	(7)	25-29	-	55	73	95	-

(n) = number of trials

In Mediterranean areas, *A. fatua*, *A. ludoviciana* and *A. sterilis* also proved to be highly susceptible to CGA 184'927+S (Table 4). At rates of 40-60 g a.i./ha weed control exceeded 95 % and was clearly superior to the standard material. Again, applications to advanced growth stages (GS 29/30) did not have any detrimental effects on the excellent *Avena* control obtained from CGA 184'927+S. *Lolium rigidum* as well as *Phalaris* spp. were very well controlled with 60 g a.i./ha of CGA 184'927+S.

TABLE 4. Percentage control with CGA 184'927+S against annual grasses in winter wheat (Italy, Spain 1986-88)

Grass species	(n)	GS at application	CGA 184'927+S g a.i./ha 40	60	diclofopmethyl g a.i./ha 900
A. fatua	(2)	13-29	98	98	93
A. ludoviciana	(14)	13-32	95	98	75
A. sterilis	(9)	12-30	98	100	87
L. rigidum	(6)	11-25	88	95	100
P. minor	(2)	13-24	73	95	78
P. paradoxa	(2)	13-23	92	97	71

(n) = number of trials

TABLE 5. Percentage control with CGA 184'927+S against annual grasses in spring wheat (Canada, 1987-88)

Grass species	(n)	GS at application	CGA 184'927+S g a.i./ha * 40	60	80	diclofopmethyl g a.i./ha * 800
A. fatua	(17)	12-22	85	95	96	34
Setaria glauca	(3)	11-15	82	90	90	69
Setaria viridis	(10)	11-14	68	86	88	49

(n) = number of trials
* all treatments applied in a tank-mix with 1.0 % v/v of an oil additive

TABLE 6. CGA184'927 + S: Percentage phytotoxicity and grain yield of winter wheat (Europe, 11 trials) and spring wheat (Canada, 6 trials); no or low grass weed infestations

Treatment	g a.i./ha	Winter wheat % phytotoxicity 12-20 DAT	30-40 DAT	Yield t/ha*	Spring wheat % phytotoxicity 15 DAT	36 DAT	Yield t/ha*
CGA 184'927+S	60	1	0	7.65 a	0	1	2.34 a
	120	2	1	7.66 a	2	0	2.29 ab
isoproturon	3000	6	6	7.21 b	-	-	-
diclofop-methyl	1600	-	-	-	4	0	2.14 b
Untreated	-	-	-	7.43 ab			2.31 ab

* = Tukey-test; p = 0.05

The performance of CGA 184'927+S in extensively grown spring wheat in Canada is shown in Table 5. CGA 184'927+S applied at 60 g a.i./ha and in a tank-mix with an oil additive (1.0 % v/v), gave excellent control of *Avena fatua*. Acceptable control of *Setaria viridis* was obtained with 60-80 g a.i./ha of CGA 184'927+S. Control of *Setaria* spp. was most effective at the two to four leaf stage. In contrast to the standard diclofop-methyl, CGA 184'927+S provided highly consistent activity also under very dry conditions which prevailed in many of the trials in 1987 and 1988.

CGA 184'927+S was very well tolerated by winter and spring wheat (Table 6). Visual symptoms of crop phytotoxicity were negligible. Yield values at both normal and double the anticipated rate did not differ from untreated control plots. These results clearly demonstrate the excellent performance of the experimental safening compound CGA 185'072 for selective protection of wheat crops from CGA 184'927 injury.

DISCUSSION

CGA 184'927+S offers a very promising performance profile for the post-emergence control of important grass weeds in cereals worldwide. The unique properties of this compound include a broad spectrum of grass control, low rates of use (40-80 g a.i./ha), a high flexibility with regard to application timing and finally a very consistent performance under different climatic conditions. *Avena* spp. (40-60 g a.i./ha) and *Alopecurus myosuroides* (50-60 g a.i./ha) are the most susceptible grasses. In contrast to many of the present standards, CGA 184'927+S is less dependent on weed growth stage and can therefore be applied against both species from the three leaf stage up to early shooting (Cornes et al., 1989). At the rate of 60 g a.i./ha, CGA 184'927+S also provides good control of other important grass weeds such as *Lolium* spp., *Phalaris* spp., *Poa trivialis* and *Setaria* spp.

CGA 184'927+S performs best when grasses are actively growing in warm conditions with adequate soil moisture. However, as the trial results from Canada show, CGA 184'927+S performs consistently well under different climatic conditions and also provides consistent high levels of grass weed control under adverse dry conditions. For optimal performance in extensive cereals, especially against drought stressed grasses, CGA 184'927+S should be applied in conjunction with the recommended amount of an oil additive (for example mineral oil or crop oil concentrate).

The safener CGA 185'072 fully protects wheat from injury by CGA 184'927. This herbicide/safener combination provides a wide crop safety margin in wheat. No variety-specific reaction or crop growth stage restrictions have been observed. Preliminary trial results also show full crop tolerance in durum wheat, rye and triticale (Cornes et al., 1989).

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HOE 70542 - A NEW MOLECULE FOR USE IN COMBINATION WITH FENOXAPROP-ETHYL ALLOWING SELECTIVE POST-EMERGENCE GRASS WEED CONTROL IN WHEAT

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ABSTRACT

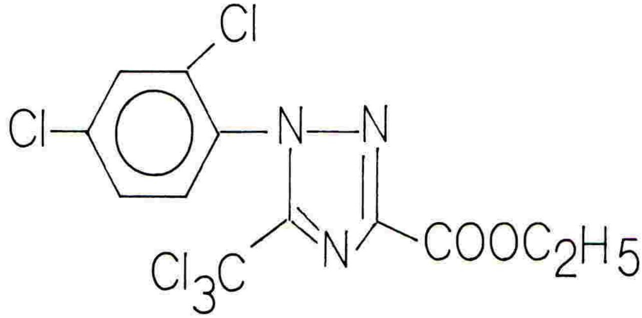
Hoe 70542, ethyl-1-(2,4-dichlorophenyl)-5-trichloro-methyl-1H-1,2,4-triazole-3-carboxylate, is a new foliar-acting molecule for use in combination with fenoxaprop-ethyl allowing selective post-emergence control of grass weeds in wheat, durum wheat, rye and triticale. The formulated herbicide consisting of fenoxaprop-ethyl plus Hoe 70542 has been extensively field tested covering a wide range of climatic and agricultural conditions, and consistently high activity was demonstrated against numerous grass weeds for example *Alopecurus myosuroides*, *Avena spp.*, *Apera spica-venti*, and *Phalaris spp.* Excellent control has been obtained by the use of 120-180 g a.i./ha of the herbicide fenoxaprop-ethyl combined with Hoe 70542 applied between three leaf stage and the second node stage of grass weeds.

INTRODUCTION

Fenoxaprop-ethyl was introduced as a selective herbicide for the control of grass weeds in broad-leaved crops (Bieringer *et al.*, 1982). The tolerance of small grain crops is insufficient for use by itself, with the exception of rice (Todd, 1984; Snipes *et al.*, 1987). Hoe 70542, discovered and developed by Hoechst AG, is a new foliar-acting molecule to be used in combination with fenoxaprop-ethyl to enable the selective grass weed control in wheat, durum wheat and rye. Fenoxaprop-ethyl formulated with addition of Hoe 70542 has been field tested since 1986 in the major cereal growing areas of the world and is currently registered and commercialised under the trade name 'Puma' (Huff *et al.*, 1989)

CHEMICAL AND PHYSICAL PROPERTIES

Structure:



Chemical name (IUPAC): Ethyl-1-(2,4-dichlorophenyl)-5-trichloromethyl--1H-1,2,4-triazole-3-carboxylate

Common name (proposed): fenchlorazole-ethyl

Code number: Hoe 70542 Melting point: 108-112°C

Empirical formula: $C_{12}H_8Cl_5N_3O_2$ Physical form: white, solid

Molecular weight: 403.48 Vapour pressure: 8.9×10^{-9} hPa (20°C)

Solubility:

water	0.9 mg/l (22°C)	toluene		270 g/l (20°C)
n-hexane	2.5 g/l (20°C)	acetone		360 g/l (20°C)
methanol	27 g/l (20°C)	dichlormethane	>	500 g/l (20°C)

TOXICOLOGY

The technical material (Hoe 70542) exhibited only slight toxic properties following acute treatment in different species.

Acute oral LD50
Rat > 5000 mg/kg body weight Mouse > 2000 mg/kg body weight

Acute dermal LD50
Rat > 2000 mg/kg body weight Rabbit > 2000 mg/kg body weight

The technical material (Hoe 70542) proved to be non-irritant to the skin and mucosa (eyes) of rabbits and revealed no indication of allergenic properties in guinea pigs.

Subchronic toxicity (90 day feeding study)
Dog: no effect level 80 mg/kg diet
Rat: no effect level 1280 mg/kg diet
Mouse: no effect level 80 mg/kg diet in males
320 mg/kg diet in females

Chronic toxicity (1 year feeding study)
Dog: no effect level 80 mg/kg diet

In each species liver, kidneys and blood were indentified as target organs. Hoe 70542 showed no mutagenic potential in a variety of tests with different end-points. Hoe 70542 revealed no evidence of teratogenic properties in rats and rabbits. It is not acutely toxic to mammalian wildlife, has low toxicity to birds, is not toxic to bees and has negligible effects on soil microorganisms. The toxicity studies were performed according to OECD guidelines.

MODE OF ACTION

Hoe 70542 applied by itself either pre- or post-emergence does not show any herbicide activity. With high rates of up to 10 kg a.i./ha, applied in the greenhouse no herbicide effect was shown on 8 different plants of broad-leaved, grass and sedge species.

If Hoe 70542 is applied to the foliage of wheat in combination with the grass herbicide fenoxaprop-ethyl it prevents growth redardation, leaf discolouration, and chlorosis of the crop which usually appears within a few days if fenoxaprop-ethyl is sprayed alone. In the wheat plant Hoe 70542 accelerates the metabolic breakdown of fenoxaprop-ethyl leading to a more rapid formation of non-phytotoxic degradation products (Köcher et al., 1989). In target grass weeds, however, Hoe 70542 apparently has no effect on the herbicidal activity of fenoxaprop-ethyl.

FORMULATIONS

Fenoxaprop-ethyl is formulated in combination with Hoe 70542 as an oil in water emulsion, EW 60, containing 60 g/l of fenoxaprop-ethyl and 15 g/l of Hoe 70542.

The biologically active isomer fenoxaprop-P-ethyl is formulated as EW 75, containing 75 g/l of fenoxaprop-P-ethyl and 37.5 g/l of Hoe 70542.

Other formulations of the EW type are also available utilising the same ratios 4:1 and 2:1 of herbicide to Hoe 70542 as mentioned above.

Oil in water emulsions contain a small amount of solvent and the active ingredient is dissolved in the oil phase. All the EW formulations mentioned here show low acute toxicity following oral or dermal exposure.

MATERIALS AND METHODS

Outdoor pot trials were replicated fourfold. Plants were treated at the early tillering stage (GS 21-22) at a water volume of 300 l/ha. Assessments and/or dry weights were taken 4 weeks after herbicide application.

Field trials conducted in Spain, Germany, France, Italy and Canada were of randomised block design using 3 or 4 replicates. Plot size was 2 m x 5 m. All treatments were applied with hand held plot sprayers at volume rates of 300-400 l/ha using 'Tee-Jet' nozzles at a pressure of about 200 kPa. Visual assessments were made to determine herbicidal efficacy.

RESULTS

Crop tolerance

The results of outdoor pot studies demonstrate the high tolerance of wheat (soft and durum) to the mixture fenoxaprop-ethyl plus Hoe 70542, while wheat, particularly durum wheat, is only marginally tolerant to fenoxaprop-ethyl by itself (Fig 1).

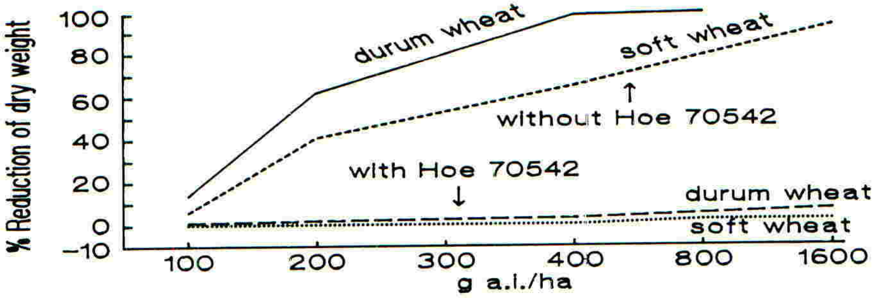


Fig.1 Tolerance of wheat to fenoxaprop-ethyl applied with and without Hoe 70542

Under weed free conditions in the field, single and double use rates (180 and 360 g a.i./ha) of fenoxaprop-ethyl were applied alone and with Hoe 70542 at different growth stages of soft wheat and durum wheat. Results of visual evaluations and yields showed clearly that even under conditions of late application when wheat is very susceptible to fenoxaprop-ethyl by itself, the compound Hoe 70542 safely protected wheat from crop damage (Huff et al., 1989). No yield reductions have been reported from use of the herbicide plus Hoe 70542 in numerous trials with different varieties under various soil and climatic conditions.

Rye and triticale are also tolerant to the combination and Hoe 70542 greatly enhanced the selectivity of fenoxaprop-ethyl in these crops.

Hoe 70542 does not affect the known high tolerance of broad-leaved crops to fenoxaprop-ethyl, thus the combination product can be selectively used in all broad-leaved crops in the same way as fenoxaprop-ethyl by itself.

Corn (Zea mays), sorghum and oats are not tolerant to fenoxaprop-ethyl with Hoe 70542. The use in barley is currently not possible although tolerance is greatly increased.

Grass weed control

Hoe 70542 did not alter the speed of herbicidal activity of fenoxaprop-ethyl against grass weeds.

Fenoxaprop-ethyl with and without Hoe 70542 was applied to two outdoor grown susceptible grass weeds at growth stage 21-22 and analysis of dry weights of plant shoots showed that there was no significant difference in the herbicidal activity.

Trials also showed that the spectrum of grasses controlled by fenoxaprop-ethyl plus Hoe 70542 is identical to that known for the herbicide component alone.

Efficacy of fenoxaprop-ethyl plus Hoe 70542 against Alopecurus myosuroides in wheat has been tested at different growth stages using rates of 120-180 g a.i./ha. Results from numerous field trials (France 1987) demonstrate the excellent weed control achieved which is virtually independent of growth stage (Fig 2).

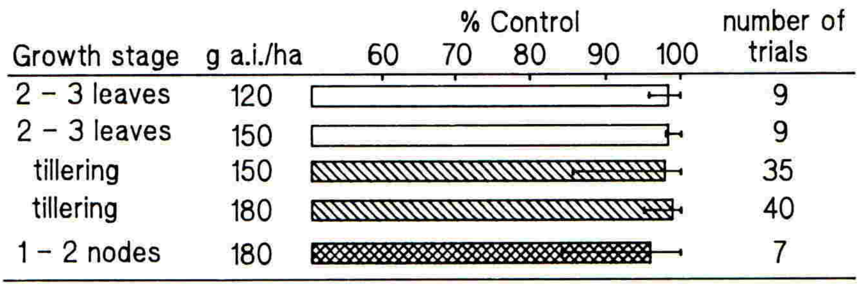


Fig.2 Control of Alopecurus myosuroides in wheat by fenoxaprop-ethyl plus Hoe 70542 applied at different growth stages (France 1987)

The effectiveness against annual grass weeds Avena spp., Apera spica-venti and Phalaris spp. in 4 countries in 1986 is shown in Table 1. At rates of 120-180 g a.i./ha fenoxaprop-ethyl with Hoe 70542 gave high levels of Avena control even if applied at late tillering or at 1-2 node stage.

TABLE 1.
Efficacy of fenoxaprop-ethyl (plus Hoe 70542) against various grass weeds in wheat applied at different growth stages (Italy, Canada, Germany and France,1986)

Grass weed	Growth stage	Number Weeds/m^2 (untreated)	% Control g a.i./ha 120	150	180	Number trials
Avena spp.	10 - 22	141	97	99	100	11
	22 - 30	105	-	98	99	20
	31 - 32	128	-	-	99	6
Apera spica-venti	13 - 25	216	92	93	99	12
Phalaris spp.	14 - 21	206	97	98	99	9

Activity of racemate versus isomer of fenoxaprop-ethyl

In 6 field trials racemic fenoxaprop-ethyl plus Hoe 70542 in a 4:1 ratio was compared with the isomer fenoxaprop-P-ethyl plus Hoe 70542 in a 2:1 ratio. Visual assessments showed that about a half of the active ingredient of the biologically active isomer is required to provide the same level of grass weed control which is achieved by the racemate and Hoe 70542 did not affect the herbicide activity of either compound (Huff et al., 1989).

CONCLUSIONS

Fenoxaprop-ethyl formulated with the special foliar-acting molecule Hoe 70542 is a new highly selective post-emergence herbicide for use in soft wheat, durum wheat, rye and triticale to control a wide range of annual grass weeds. It is highly effective, used at low rates of 120 - 180 or 60 - 90 g a.i./ha of racemate or active isomer, respectively, and offers a very good flexibility of timing of application from 3 leaves to 1 - 2 node growth stage of grass weeds.

Due to favourable toxicological data and outstanding biological properties fenoxaprop-ethyl plus Hoe 70542 shows considerable potential as a new systemic graminicide for wheat and rye crops.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance of other Hoechst technical and research personnel for generating and assimilating the information reported in this paper.

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CGA 163'935, A NEW PLANT GROWTH REGULATOR FOR SMALL GRAIN CEREALS, RAPE AND TURF

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ABSTRACT

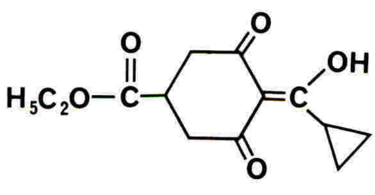
CGA 163'935 is a new plant growth regulator active as a growth inhibitor on a wide variety of monocotyledonous and dicotyledonous plants. The main areas of its potential use are for prevention of lodging in small grain cereals, growth inhibition to prevent lodging and to improve harvestability and yield in rape and growth inhibition of cool and warm season turf grasses. This paper releases the chemical structure of CGA 163'935 and describes physical and chemical properties of the active ingredient. Results from greenhouse experiments indicate that CGA 163'935 is taken up by the foliage and translocated to the growing shoot, where it affects internode elongation. It appears to have little action on photosynthesis, root growth and plant development. Data from field trials illustrate the potential of CGA 163'935 to prevent lodging and associated yield losses.

INTRODUCTION

With the introduction of chlormequat for wheat in the mid-sixties and ethephon for barley in the mid-seventies, the use of growth regulators has become common practice in intensive cereal production. The expansion of the area of oilseed rape grown in Europe in recent years together with more intensified production systems have led to the search for antilodging compounds for this crop too. The successful use of growth inhibitors in turf is highly dependent on the type of turf (cool and warm season), the grass species present and the quality requirements. CGA 163'935 is a new plant growth regulator from a new chemical group discovered and currently being developed by Ciba-Geigy Ltd., Basle. This paper describes its chemical, physical and biological properties, its use to prevent lodging in small grain cereals and oilseed rape, and as a growth inhibitor for cool and warm season turf.

CHEMICAL AND PHYSICAL DATA

Chemical name: ethyl 4-cyclopropyl(hydroxy)methylene-3,5-dioxocyclohexanecarboxylate
Structural formula:



Code number: CGA 163'935
Empirical formula: $C_{13}H_{16}O_5$
Molecular weight: 252.3
Melting point: 36.0°C
Vapour pressure, 20°C: 1.6×10^{-3} Pa
pKa value: 4.7

Solubilities at 20°C:			
water, pH 7	27 g/l	cyclohexanone	> 1 g/ml
water, pH 5	5 g/l	isopropanol	0.9 g/ml
methanol	>1 g/ml	n-octanol	180 mg/ml
acetonitrile	>1 g/ml	hexane	35 mg/ml

Formulation: 25% EC
Partition coefficient n-octanol/water at pH 3: log P = 2.1
at pH 7: log P = - 0.4
Toxicity of technical material:
Acute oral (rat) LD50 : 4460 mg/kg
Acute dermal (rat) LD50 : > 4000 mg/kg
Irritation, skin and eye : not irritant

SITE OF UPTAKE, PENETRATION AND TRANSLOCATION

Leaf uptake was studied under greenhouse conditions: primary wheat leaves were sprayed at a rate of 400 g a.i./ha. At 0, 4 and 24 hours after treatment, the remaining spray deposit was washed off with phosphate buffer (pH 7) and analysed by h.p.l.c. The results indicate a 50% penetration rate after 6 hours (Fig. 1). The measurement of wheat leaf growth after foliar application of CGA 163'935 (using a method by Christ, 1978) demonstrated foliar uptake and translocation: two days after treatment of the second leaf with a 30 ppm suspension of CGA 163'935, growth inhibition was detected in the third leaf (Fig. 2). In comparison with foliar activity, the activity of CGA 163'935 applied pre-emergence or as a soil drench to the roots was inferior by a factor of 10 or more (data not shown).

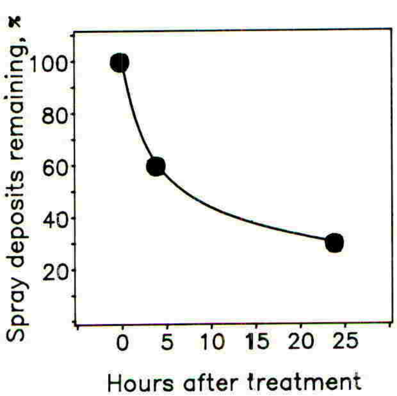


FIGURE 1. Spray deposit of CGA 163'935 on primary wheat leaves, 0,4 and 24 hours after treatment

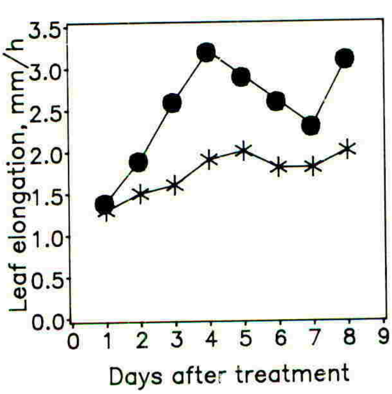


FIGURE 2. Effect of CGA 163'935 applied to the second leaf of wheat on the elongation growth of the 3rd leaf (days 1-7) and the 4th leaf (day 8). ● = untreated check, ⋆ = treated plants.

SPECTRUM OF ACTIVITY

As a growth regulator, CGA 163'935 has a wide spectrum of activity. The rates needed for a 50% growth inhibition under greenhouse conditions depend on the target species (Table 1). Rates range from 100-700 g a.i./ha for monocotyledonous and 300-1000 g a.i./ha for dicotyledonous species. These results were obtained after post-emergence application on well established plant material, evaluated at 30 DAT.

TABLE 1. Rate of CGA 163'935 needed for 50 % growth inhibition, applied post-emergence and assessed 30 DAT

Plant species	g a.i./ha	Plant species	g a.i./ha
Barley	500	Rape	600
Wheat	300	Sunflower	1000
Rye	300	Soybean	800
Triticale	300	Peanut	700
Rice	100	Potato	600
Bermudagrass	300	Clover, subterranean	300
Bahiagrass	300	Apple (seedlings)	700
Perennial ryegrass	700	Chrysanthemum, ornamental	1000

INFLUENCE ON PLANT MORPHOLOGY

The influence of CGA 163'935 on the shoot morphology of barley was assessed when field grown plants were mature and compared with untreated plants (20 per treatment, Fig. 3). A rate of 250 g a.i./ha was applied at 2 growth stages (GS 30 and GS 37). The early timing of application led to a shortening of the 3 lower internodes, the upper internodes remaining unchanged. The later application timing resulted in a shortening of internodes 4 and 5 while the 3 basal internodes remained unchanged. Both treatments resulted in an 8% inhibition of total plant height and were equally effective in prevention of lodging.

The effect of CGA 163'935 on the morphology of oilseed rape grown under field conditions was also examined (20 plants per treatment), 400 g a.i./ha, applied at GS 3,5 resulted in a height reduction of 15% at GS 6,3. This reduction of stem growth was concentrated in the lower, unbranched segment (Fig. 4). The upper plant segment with its branches and pods was not changed in total length, but the number of first order branches increased with the growth regulator treatment by more than 2 per plant.

The influence of CGA 163'935 on wheat root growth was studied under greenhouse conditions in soil cylinders (ø 15 cm, 100 cm length). Rates of 0.5 to 2.0 kg a.i./ha were applied at the 3 leaf stage and root and shoot length measurements were made at 30 DAT. While CGA 163'935 had a clear inhibitory activity on shoot elongation, no effect could be observed on root length (Fig. 5).

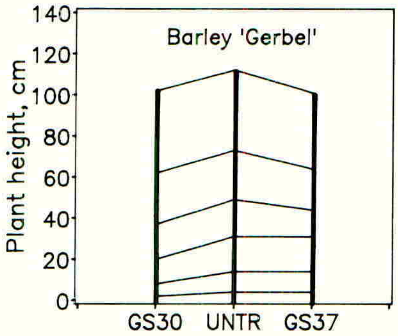


FIGURE 3. Winter barley cv. Gerbel: Total plant height and internode lengths of mature plants treated with CGA 163'935 at 250 g a.i./ha at two application timings (GS 30 and GS 37). UNTR = Untreated

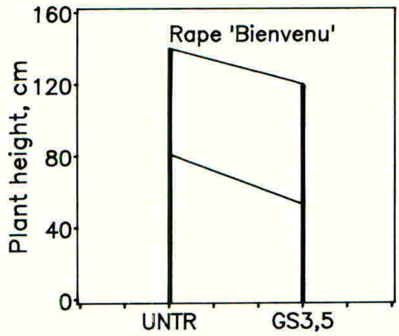


FIGURE 4. Winter rape cv. Bienvenu: Total plant height, length of the unbranched stem segment and of the upper, branched, pod bearing stem segment. Treatment: CGA 163'935 at 400 g a.i./ha (GS 3,5). Eval.: GS 6,3. UNTR = Untreated

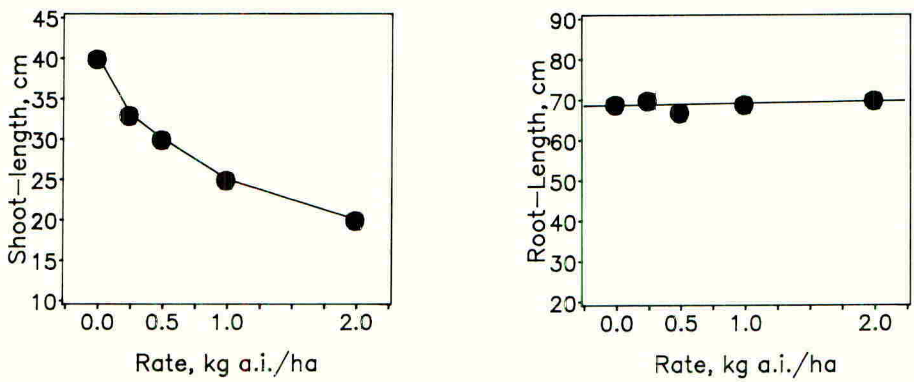


FIGURE 5. Dose-effect of CGA 163'935 on shoot and root growth of wheat, applied post-emergence.

INFLUENCE ON PHOTOSYNTHESIS AND PRODUCTION OF CARBOHYDRATES

A growth regulator which reduces plant height should not have a negative effect on yield relevant physiological processes and to confirm this, photosynthesis of wheat was studied under field conditions. CGA 163'935 applied at GS 37 at rates up to 500 g a.i./ha resulted in growth inhibition of up to 30%, measured at GS 69. At GS 69 photosynthesis was measured employing cuvettes covering an area of 0.2 m^2. Even with growth inhibitions of 30%, no reduction of net photosynthesis per unit of canopy area compared with untreated plants could be detected (Fig. 6, R.A. Christ, unpublished data). This inhibition, together with unchanged photosynthetic performance should lead to an excess of assimilates available for intermediate storage. This hypothesis was studied under controlled conditions (20/15°C, 300 μ E/m^2/sec PAR): CGA 163'935 was applied to the roots (nutrient solution) of 9 day old seedlings at rates high enough to inhibit shoot elongation. Total sugar content measured 4 DAT (anthron method) in the shoots increased with increasing rates of CGA 163'935 (Fig. 7). Chromatographic analysis (Wagner *et al.*, 1983) showed that mainly the fructans were increased in concentration. This data could be one reason for the unchanged yield values in cases where CGA 163'935 was applied to small grain cereals under non-lodging conditions (Fig. 8, wheat).

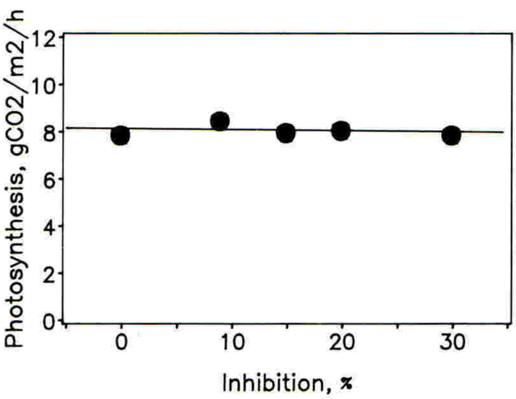


FIGURE 6. CO_2 consumption and growth inhibition of field grown wheat cv. Probus, treated with CGA 163'935 at GS 37 and evaluated at GS 69.

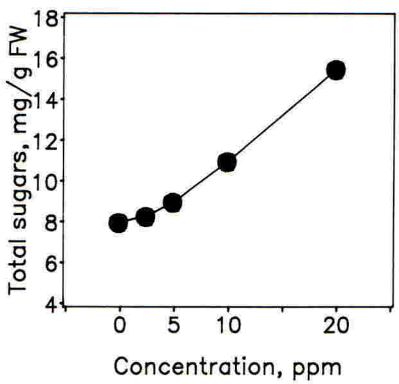


FIGURE 7. Content of total sugars in wheat, treated with different rates of CGA 163'935. (FW = shoot fresh weight).

FIELD EXPERIMENTS

The cumulated data of international field testing of CGA 163'935 in cereals and oilseed rape are reported by Amrein *et al.* (1989) and the data on turf inhibition will be reported by Porpiglia *et al.* (1989) and Somody *et al.* (1989). Data illustrating the potential of CGA 163'935 in small grain cereals was derived from 3 randomised complete block field trials with 3 replications and plot size of 12 m^2 carried out in Switzerland 1986. Winter wheat, winter barley and winter rye were treated in the spring at GS 34-37. Heavy rainfall caused severe lodging in barley 11 days after treatment and later, nearly complete lodging occurred in rye as well. Evaluation of the percentage crop area lodged at GS 69 (Fig. 8) demonstrate the ability of the growth regulator to prevent lodging in barley and rye. By means of this reduced lodging, substantial yield losses were prevented. In the case of wheat where no lodging occurred, the treatment had no influence on yield.

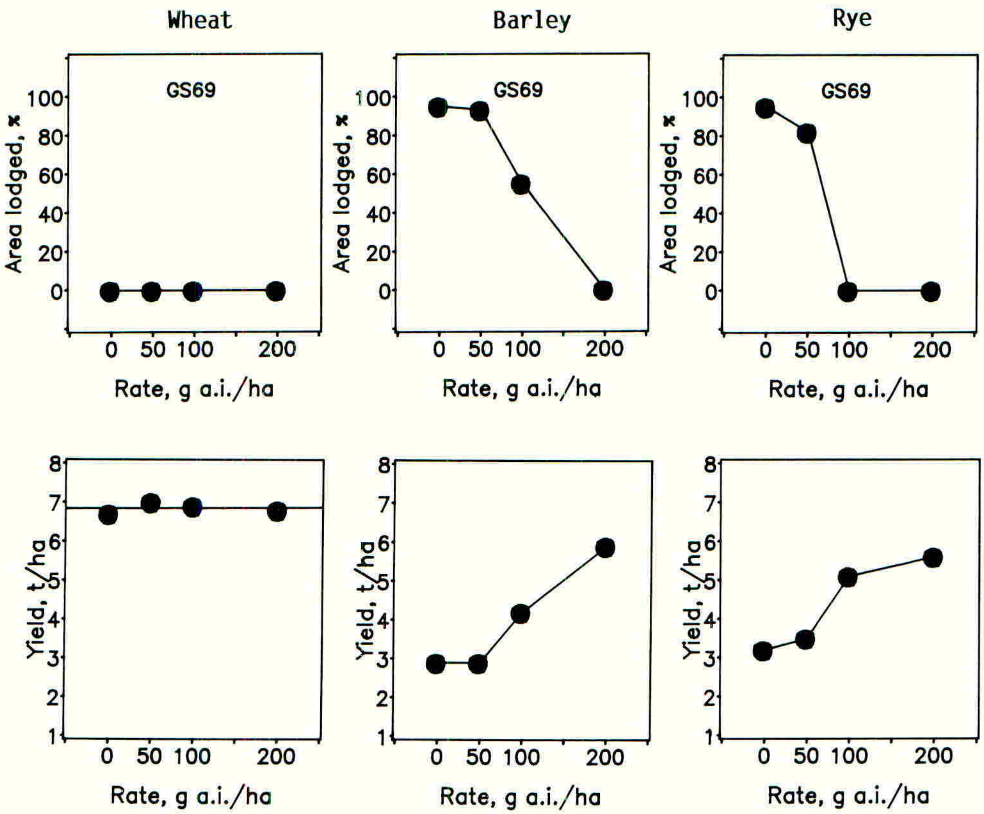


FIGURE 8. Influence of CGA 163'935 applied at GS 34-37 on lodging and grain yield in field grown wheat, barley and rye.

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THE USE OF CGA 163'935 AS A GROWTH REGULATOR IN CEREALS AND OILSEED RAPE

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ABSTRACT

CGA 163'935, a new growth regulator, exhibits excellent properties for the prevention of lodging in cereals and winter oilseed rape. Use-rates are crop dependent and vary between 100-250 g a.i./ha in small grain cereals and 400-600 g a.i./ha in winter oilseed rape. In cereals, CGA 163'935 application timing is quite flexible during the period of stem elongation (GS 31-39) and in oilseed rape, at a crop height of 10-25 cm. It reduces crop height and provides excellent control of lodging in both crops. In trials where lodging occurred, applications with CGA 163'935 prevented average yield losses of 5-14%. In the absence of lodging, CGA 163'935 has no detrimental effects on yield and offers a wide crop safety margin.

INTRODUCTION

Today growth regulators are successfully used on a wide range of food, turf and ornamental plants. In intensively grown cereals in Western Europe, growth regulators have become an integral part of the cereal production system. Several compounds are marketed to shorten the crop height, to strengthen the basal or upper internodes and consequently to reduce lodging of cereal crops. Therefore, farmers are using plant growth regulators to protect the quality and yield potential of cereal crops and to secure their financial investments in the crop against late damage caused by lodging.

The oilseed rape plant is tall and top-heavy due to the presence of a dominant terminal raceme, thus rape crops often lodge severely during pod development especially after periods of heavy rainfall. Therefore, the search for new chemicals which inhibit or retard growth of oilseed rape is an active field of research (Child et al., 1987).

CGA 163'935 is a new plant growth regulator, which is currently being investigated by Ciba-Geigy Ltd., Basle. The chemical and physical properties of this compound are reported by Kerber et al., (1989). This paper describes field trial results on the use of CGA 163'935 for reducing the risk of lodging in cereal and in oilseed rape crops.

MATERIALS AND METHODS

Field trial programmes with CGA 163'935 were carried out from 1987 to 1989 in Western Europe. The experimental design was a randomised complete block containing four replicates. Plot size varied from 10-50m^2. Applications were made using a CO_2 pressurized small plot sprayer, calibrated to deliver a spray volume of 200 l/ha. CGA 163'935 was formulated as emulsifiable concentrate. Standard compounds were commercially available formulations. Programmes for fertiliser application and disease, pest and weed control were carried out by the farmers and were those appropriate for each site with regard to soil type, variety and local agricultural practice.

Crop phytotoxicity and height were assessed visually at various intervals after application on a 0-100% rating scale (0% = no effects). Oilseed rape growth stages (GS) were defined according to Schütte et al., (1982) and the decimal code was used for cereals. Lodging was visually assessed by estimating the % plot area affected. The degree of lodging was assessed on a 0-100 scale where 0 = stems erect, no lodging and 100 = stems horizontal, completely lodged (Laermann, 1986). The lodging index was calculated according to Bolten et al., (1987).

$$\text{Lodging index} = \frac{\%\ \text{area lodged} \times \text{degree of lodging}}{100}$$

Plots were harvested using a small plot combine harvester and seed yields were corrected to 15% moisture content for cereals and 5% for oilseed rape. The thousand seed weight (TSW) and seed moisture were also measured. Statistical analyses of variance were performed on seed yield.

RESULTS

Winter barley (Table 1)

Results with CGA 163'935, when applied at 150-250 g a.i./ha and at two different application timings (GS 31-32 and GS 37-39 respectively), are depicted in Table 1. CGA 163'935 reduced crop height of winter barley at both application timings. The degree of height reduction at each timing was dose dependent. Crop height reduction was greater for applications during early stem elongation and reached average levels of 12-13% at rates of 200-250 g a.i./ha. The standard compound ethephon also reduced crop height; however it was less effective than CGA 163'935 with 200-250 g a.i./ha at either timing.

CGA 163'935 considerably reduced early and late lodging (GS 69-79 and GS 81-85 respectively). The degree of lodging prevention was also dose dependent. Lodging was most consistently reduced, when CGA 163'935 was applied at crop growth stages 31-32. CGA 163'935 clearly outperformed the commercial standard ethephon, when applied at 200 g a.i./ha at early application timing (GS 31-32) and at 250 g a.i./ha during the flag leaf stage (GS 37-39).

The prevention of lodging by CGA 163'935 resulted in an average yield benefit of 7-9% as compared to the untreated control plots. Increased efficacy in lodging reduction was linked with higher crop yields, although treatments with CGA 163'935 were not statistically different with regard to rates of use application timings, or from the commercial standard.

TABLE 1. Effects of CGA 163'935 on crop height, lodging and yield of winter barley (mean of 14 trials in France, Germany, Switzerland and UK; 1987 and 1988)

Treatment	g a.i./ha	Crop GS at application	% crop height reduction at GS 59-61	Lodging at GS 69-79		Lodging at GS 85-89		Yield
				% area lodged	lodging index	% area lodged	lodging index	t/ha*
Untreated		-	-	55	35	72	55	6.19a
CGA 163'935	150	31-32	4.4	12.4	5.0	25.5	13.6	6.64b
	200	31-32	11.8	5.0	1.8	14.0	6.6	6.74b
	250	31-32	12.8	1.6	0.3	5.6	2.2	6.77b
CGA 163'935	150	37-39	5.9	18.8	8.1	38.7	23.4	6.65b
	200	37-39	8.6	10.1	4.2	29.2	18.7	6.70b
	250	37-39	9.5	7.8	3.1	21.7	10.1	6.80b
ethephon	480	41-49	7.2	8.4	3.3	25	14.6	6.66b

* Tukey-test; $\underline{P} = 0.05$

TABLE 2. Effects of CGA 163'935 on crop height, and yield of winter wheat (mean of 8 trials in France, Germany and Switzerland; 1987 and 1988)

Treatment	g a.i./ha	Crop GS at application	% crop height reduction at GS 59-61	Lodging at GS 81-85		Yield
				% area lodged	lodging index	t/ha*
Untreated		-	-	79.7	59.4	6.74a
CGA 163'935	100	31-32	5.8	25	12	7.58b
	150	31-32	9.9	5.9	0.8	7.71b
CGA 163'935	100	37-39	9.1	18.8	8.3	7.60b
	150	37-39	13.4	6.3	2.4	7.67b
chlormequat + choline chloride	780-1560	25-29	7.1	18	10.2	7.70b

*Tukey-test; $\underline{P} = 0.05$

Winter wheat (Table 2)

CGA 163'935 reduced final crop height of winter wheat (GS 59-61) at rates of 100-150 g a.i./ha and at both application timings (GS 31-32 and GS 37-39 respectively). The degree of inhibition was also dose-dependent and slightly more effective with an application at the flag leaf stage of the crop (GS 37-39). CGA 163'935 at 150 g a.i./ha was more effective in reducing crop height of winter wheat than the commercial standard.

CGA 163'935 also effectively reduced lodging of winter wheat. In this respect, there were few differences between applications at the early shooting stage (GS 31-32) and at the flag leaf stage (GS 37-39). However, the degree of lodging prevention was dose-dependent. At either application timing, 150 g a.i./ha of CGA 163'935 gave almost complete control of lodging (lodging index 0.8 and 2.4 respectively). At this rate CGA 163'935 performed better than the commercial standard.

The high degree of reduced lodging of winter wheat prevented yield losses of 12-14%. There were no statistical differences between treatments of CGA 163'935 nor between CGA 163'935 and the commercial standard.

Crop tolerance to winter wheat and barley (Table 3)

A range of trials, where no lodging occurred, have been selected to demonstrate crop tolerance of CGA 163'935 to winter wheat and barley. Visual symptoms of crop phytotoxicity were not observed any time during the trial period. Yield results with CGA 163'935 at normal and twice the recommended field rate were not statistically different from untreated control plots. These results were also comparable to those with reference products.

Winter oilseed rape (Table 4)

CGA 163'935 reduced plant height of winter oilseed rape and the degree of height reduction was dose-dependent. The rate of growth was similar between treated and untreated plants. However crop height of treated plants was reduced by 10-22% at the first evaluation date (GS 51) and the final crop height (GS 70) was reduced by 8-18%. CGA 163'935 at 400 g a.i./ha and ethephon at 1230-1380 g a.i./ha achieved similar levels of crop height reduction.

CGA 163'935 considerably reduced lodging of winter oilseed rape. The degree of lodging prevention was dose-dependent within the range of rates 200-600 g a.i./ha. At either rate, CGA 163'935 was more effective in lodging prevention than the application with ethephon. The considerable reduction of lodging of winter oilseed rape, as achieved by CGA 163'935 at 400-600 g a.i./ha, prevented crop yield losses of 0.13 t/ha. Crop yields with ethephon were no different from untreated control plots.

TABLE 3. Influence of CGA 163'935 on crop yield of winter barley (mean of 11 trials) and wheat (mean of 5 trials) in the absence of lodging (France, Germany, Switzerland and UK; 1987-1989)

Treatment	g a.i./ha	Crop GS at application	Winter barley t/ha*	Winter wheat t/ha*
Untreated			6.58a	7.29b
CGA 163'935	200	31-32	6.69a	
	400	31-32	6.49a	
	400	37-39	6.56a	
ethephon	960	41-49	6.64a	
CGA 163'935	125	31-32		7.46b
	250	31-32		7.40b
	250	37-39		7.20b
chlormequat + choline chloride	4000	25-29		7.30b

*Tukey-test; $\underline{P} = 0.05$

TABLE 4. Effect of CGA 163'935 on crop height, lodging prevention and crop yield in oilseed rape (mean of 4 trials in Germany, Switzerland and UK; 1987)

Treatment	g a.i./ha	% crop height reduction GS 51	GS 60	GS 70	Lodging reduction at GS 83-90 % area lodged	lodging index	Yield t/ha*
Untreated≠		120 cm	136 cm	140 cm	77.5	43.3	2.87a
CGA 163'935	200	10.2	8.9	8.2	28.0	7.7	2.97a
	400	15.1	12.9	12.5	11.3	3.2	3.01a
	600	20.5	15.7	17.0	3.3	1.0	3.00a
	800	22.1	19.5	18.3	3.4	1.0	2.98a
ethephon	1230-1380	17.5	14.1	12.1	40.8	14.0	2.80a

≠Crop growth stages at application GS 33-39; crop height 10-25 cm
*Tukey-test; $\underline{P} = 0.05$

DISCUSSION

CGA 163'935 shows unique properties as a growth regulator for several agricultural crops. In cereals, it induces stem shortening and shows a high potential for lodging reduction in both winter wheat and barley. Its potential in winter rye is reported by Kerber et al., (1989). As CGA 163'935 provides flexibility of application timing during the period of stem elongation of cereal crops, it can be beneficially integrated with other plant protection measures, especially with fungicide applications. In winter wheat and barley, CGA 163'935 prevented considerable yield losses mainly due to the control of early, and severe incidences, of lodging.

CGA 163'935 also reduced plant height of winter oilseed rape, and this effect persisted. The height remained reduced until harvest and the degree of lodging was considerably less. The benefit of lodging control in oilseed rape provided by CGA 163'935 may not only consist in preventing crop yield losses but also in improving harvesting. It should be noted, that the amount of vegetative material from a shorter and non-lodged crop passing through the combine is substantially reduced.

The versatility of CGA 163'935 is also documented by its excellent performance as a growth retardant in warm and cool season turf species (Porpiglia et al., 1989; Somody et al., 1989). The evaluation of other agricultural uses is in progress.

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SESSION 3A

INTEGRATION OF CEREAL CROP MANAGEMENT WITH WEED CONTROL: PRACTICAL ASPECTS

CHAIRMAN	MR A. J. BIDE	
SESSION ORGANISER	MR M. N. TALBOT	
INVITED PAPER		3A-1
RESEARCH REPORTS		3A-2 to 3A-7

THE INTEGRATION OF PEST AND DISEASE CONTROL WITH WEED CONTROL IN WINTER CEREALS IN GREAT BRITAIN

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ABSTRACT

The intensive growing of cereals, particularly winter cereals, has been made possible by herbicides and chemical fertilisers. Such systems now depend on relatively high inputs of pesticides which often need to be applied at specific times. The number of spray occasions available to the farmer is frequently severely limited by the weather. This limitation has led increasingly to the use of tank-mixes for the control of weeds and/or diseases and/or pests. It has been argued that such tank-mixes are often applied when the conditions or the growth stage of the crop are not correct for one or more of the constituents. Spray applications for pest and disease control and for growth regulation are usually time specific. However, modern herbicides can be applied at a range of timings to obtain reliable weed control. In addition there is a long period of time over which weeds can be controlled before they reduce yield. Hence, the integration of economic chemical weed, pest and disease control and growth regulation in the form of tank-mixes of pesticides is often possible without conflict or compromise. The notable exceptions to this conclusion are highlighted. The integration of cultural control measures for pest, disease and weed control are also discussed and again there are some notable conflicts between objectives. Also briefly discussed is the impact of weeds on the pest and disease status of cereal crops and the direct influence of herbicides on cereal diseases.

INTRODUCTION

Cereal production has been transformed by the introduction of chemicals that "feed and weed" crops and thereby largely replace the role of the traditional rotation. "Artificial" fertilisers, based on inorganic chemistry, were introduced in the last century and selective herbicides, based on organic chemistry, have been introduced over the last 40 years. Together they have made it possible for farmers to intensify cereals on land suited to their production. Not only has there been an intensification of cereal production but also a trend to the higher yielding winter rather than spring crops. Virtually all the wheat and two thirds of the barley is now autumn sown. This has led to a further increase in weed pressure which in turn has led to further herbicide use. Effective herbicides have also allowed changes to some of the major husbandry practices of winter cereals, particularly primary cultivation methods and date of drilling. This in turn has led to even further encouragement of weeds, particularly annual grasses. Intensification of cereals has also resulted in greater disease and pest pressure. The introduction of more effective insecticides in the 1960s and more effective fungicides in the 1970s now contributes towards the reliable production of cereals in intensive cropping sequences including continuous winter cereal production on heavy land. As a result of artificial fertilisers and pesticides, plus the advances in plant breeding, mechanisation and drainage, the yield of cereals has increased dramatically over the last twenty years (Silvey, 1986).

Therefore, modern cereal production, particularly intensive winter cereal production, can involve large usage of herbicides, fungicides and insecticides. In addition, growth regulators are commonly used. This has resulted in the farmer adopting tank-mixes to save on application costs and to ensure that with the often limited number of spray occasions, the relevant crop protection agents are applied at the correct time (Table 1). This paper examines the impact of weeds on the pest or disease status of the cereal crop, the effect of herbicides on cereal diseases and the integration of weed control with other crop protection measures and discusses whether there is any conflict or compromise between the differing objectives. Both cultural and chemical weed control measures are discussed. The impact of husbandry practices on weed control in cereals has been discussed in detail elsewhere (Orson, 1987). Limited space does not allow for a review of the impact of all husbandry factors on the integration of weed, pest and disease control.

TABLE 1. Number of spray occasions (Spackman, 1983) of five hours at Waddington (Lincolnshire) available for a low-ground pressure vehicle between 1970 and 1988 (Spackman, pers. comm.).

	Month								
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Soil-applied herbicides									
Average	23	17	9	6	5	9	13	20	23
Worst year in 10	17	10	4	3	1	0	6	10	13
2-(Aryloxy)alkanoic acids									
Average	19	10	1	0	0	1	3	11	17
Worst year in 10	10	4	0	0	0	0	0	2	8

IMPACT OF WEEDS ON THE PEST AND DISEASE STATUS OF WINTER CEREALS

In general, there is little significant interaction between weed infestations and pests and diseases but there are important exceptions (Heitefuss, 1986).

Emerged volunteer cereals act as a "green bridge" and if not controlled can be a source of obligate parasites, such as Puccinia striiformis (the yellow rust fungus) and barley yellow dwarf virus, to emerging crops in the same or neighbouring fields. Emerged volunteer cereals and some annual grass weeds, if not controlled at drilling, can act as primary sources for aphid borne barley yellow dwarf virus and cause problems with Oscinella frit (frit fly) in late drilled crops of cereals which otherwise would not suffer from the problem. There has been an association between high populations of Alopecurus myosuroides (black-grass) and Claviceps purpurea (ergot) in wheat in years when there has been heavy rain during the flowering period of the weed. The presence of Elymus repens (common couch) or its rotting rhizomes has encouraged Gaeumannomyces graminis (the take-all fungus). Weed control in cereals suffering from take-all is particularly important because of the need for adequate nutrition of the limited root system. Avena spp. (wild-oat) and certain other weeds can act as hosts to nematodes which occasionally attack cereals on light soils. Finally, high levels of vegetation, such as a weedy cereal crop, may encourage slugs.

CULTURAL CONTROL OF WEEDS, PESTS AND DISEASES IN WINTER CEREALS

Between successive winter cereal crops there is limited time available for cultural measures to control weeds, pests and diseases. It is partly for this reason that intensive cereal systems rely heavily on pesticides. The cultural control measures which are attempted aim to kill weeds which are difficult if not impossible to control in the following cereal crop, such as Bromus sterilis (barren brome) and volunteer cereals, or which increase the risk of the transfer of barley yellow dwarf virus or fungal pathogens such as P. striiformis to the following crop.

The objectives of cultural control of weeds and obligate parasitic diseases may conflict. The objective for weed control is either to bury the seeds to a depth from which they will not emerge or to encourage viable seeds to grow so that they can be destroyed by cultivation or non-selective herbicides. This latter objective can be different from that of trying to prevent a green bridge for cereal diseases or pests.

Straw burning

Straw burning reduces weed, pest and disease problems in the succeeding winter cereal crop. It kills some weed seeds, including volunteer cereals, on or near the soil surface but this does not mean that the need for weed control in the following crop is avoided or indeed significantly reduced. The exceptions are B. sterilis, other Bromus spp. and volunteer cereals which can be controlled effectively by straw burning but not reliably with selective herbicides. Obviously, the control of weed seeds is dependent on the heat generated and the proportion of the field effectively burnt. The straw burning operation can also reduce the number of slugs and may destroy green material which will act as a green bridge for cereal diseases or as a host for the aphid vectors of barley yellow dwarf virus. The inoculum of trash borne pathogens such as Pyrenophora teres, the net blotch fungus of barley, can also be reduced. Environmental pressures have decreased the amount of straw burning in recent years.

A possible conflict between straw burning for weed control and disease control is that surviving weed seeds are often less dormant. Provided that the soil is moist, there is often a "bloom" of annual grass weed growth after straw burning. This "bloom" presents an ideal opportunity to destroy the plants from weed seeds surviving straw burning. However, it can act as a green bridge for the survival and transfer of cereal diseases and pests to the following or neighbouring crops if it is not destroyed before these crops emerge.

There are also drawbacks associated with straw burning. Burnt straw adsorbs many soil-applied herbicides. If straw burning is an annual event and the burnt residues are not dispersed by relatively deep cultivation or by ploughing, the efficacy of many of the soil-applied herbicides can be reduced.

Stubble cultivation

The use of non-selective herbicides rather than stubble cultivation offers more effective control of some weed species and diseases.

In the absence of straw burning, many farmers carry out shallow cultivations immediately after harvest for various reasons. Where straw is to be incorporated without ploughing there is a distinct advantage to an early start in terms of yield of the subsequent cereal crop. Cultivation prior to ploughing encourages a more rapid break down of the straw. However, this does not result in a higher yield from the succeeding crop. On the other hand, incorporation prior to ploughing can have practical advantages. With better mixing of the straw and soil there is likely to be more nitrogen immobilised during the winter months and hence less nitrate leaching. Also, on heavier soils there is the prospect that cultivation prior to ploughing may ease the production of a seedbed after ploughing. Finally, cultivation straight after harvest may stimulate the germination of some weed species. However, whilst early cultivation may stimulate the germination of B. sterilis and in some years the germination of volunteer cereals, it prevents the loss of Avena fatua seed on the soil surface and in some years can increase the dormancy of volunteer cereals. Therefore, with certain weeds the common objective of preventing a green bridge and reducing viable weed seed is best served with the use of non-selective herbicides rather than cultivation. There is the added advantage that the use of a non-selective herbicide, such as paraquat, can reduce the green bridge transfer of the aphid vectors of barley yellow dwarf virus. Non-selective herbicides can also suppress the sporulation of pathogens such as P. teres and Septoria nodorum though not the sporulation of Rhynchosporium secalis on plant debris on the soil surface (Harris & Grossbard, 1978; Jordan & Allen, 1984; Stedman, 1980). The practical significance of this effect may be small since the reduction of sporulation of P. teres did not lead to a significant reduction of net blotch in the succeeding winter barley crop (Jordan & Allen, 1984).

Where straw burning is carried out, farmers are legally obliged to cultivate within 36 hours. This may encourage a fuller germination of Bromus spp. and volunteer cereals. However, it is of little or no advantage for encouraging the germination of A. myosuroides and may prevent loss of A. fatua from the soil surface.

Stubble cultivation used to be one of the most effective measures for the control of perennial grass weeds. However, it was necessary to repeat the cultivations in order to reduce significantly the number of viable buds on the storage organs and/or to exhaust them. This inevitably resulted in a delay in drilling. The introduction of glyphosate has given the farmer access to more effective control without a delay in drilling. Therefore, it is now unusual for farmers to try to control perennial grasses by cultural means.

Primary cultivation for winter cereals

Historically, ploughing has been used to reduce weed problems, to minimise the risk of infection with some fungal diseases and to reduce the risk of certain pests in successive cereal crops by burying all residues of the previous crop.

Ploughing is now commonly carried out to control *B. sterilis* and volunteer cereals. It also reduces the herbicide adsorption of the soil surface layers, due to organic matter and burnt straw residues which build up with repeated shallow cultivation techniques. It is also used to bury large numbers of viable annual grass weed seeds, which may also be a result of previous shallow cultivation techniques associated with intensive winter cereal production. However, ploughing often produces a more cloddy seedbed than shallow cultivation on heavy soils. In this situation, slugs are usually more mobile in the surface horizons of the soil and hence can cause more crop damage. Similarly, if a cloddy and loose seedbed results, there can be a more rapid build up of root diseases such as take-all. Finally, ploughing down aphid infested plants of volunteer cereals and some of the annual grass weed species without allowing a sufficient interval before drilling creates, when the seedbed is warm and dry, a reservoir of these pests which may invade the following cereal at or below the soil surface. A severe attack of barley yellow dwarf virus can result if these aphids are carrying the virus. In this situation, the weed plants should be sprayed with a dessicant non-selective herbicide prior to ploughing. This application of herbicide may not be necessary for weed control alone.

Ploughing can also have other drawbacks. It can produce a cloddy and loose seedbed unsuitable for the activity of soil-applied herbicides and where weeds may establish their secondary root systems deeper than normal, which thus makes them more difficult to control.

Non-ploughing techniques may encourage the emergence of infected volunteer cereals which, if not controlled, will act as a source for the spread of barley yellow dwarf virus and some other cereal diseases. In the absence of straw burning, when large amounts of straw debris are allowed to build up on or near the soil surface, there is evidence that slug populations will be encouraged.

Delayed drilling of winter cereals

Delayed drilling of winter cereals can be an advantage for both weed and disease control particularly in reducing the risk from barley yellow dwarf virus. Although risky on heavy soils where conditions may become too wet for drilling, some farmers have used this technique where there are extremely heavy populations of *B. sterilis* and *A. myosuroides*. Later drilling of winter cereals is likely to result in lower weed populations with weed plants emerged at the time of drilling being killed by the final cultivations or by a non-selective herbicide. However, delayed drilling can result in a slower germinating crop growing under poor conditions and therefore, on heavy soils, more likely to suffer from slug damage.

Delayed drilling of winter cereals reduces tillering of individual crop plants and this may reduce the crop's ability to withstand an attack of Delia coarctata (wheat bulb fly) which in its later instars moves from the tiller initially attacked. D. coarctata only rarely occurs in intensive rotations of solely autumn-sown crops and then usually after a crop of oilseed rape.

EFFECT OF SELECTIVE HERBICIDES ON CEREAL DISEASES

There is some very limited evidence that herbicides can increase disease levels. Mecoprop salt, dicamba and ioxynil have all been associated with an increase in take-all (Tottman & Thomson, 1978). In ADAS trials, apart from the application during the winter to barley grown on sandy soils, there has been little concern regarding the yields obtained from the recommended use of these herbicides. However, there have been instances of disappointing yields when ioxynil with mecoprop has been applied to winter wheat in ideal conditions for weed control. The reason for these lower yields has not been investigated (Orson, 1988).

Herbicide usage out of recommendation may decrease the plants' ability to withstand disease infection. For instance, application of mecoprop salt to winter barley later than recommended can increase the level of powdery mildew (Orson, 1983). On the other hand, the use of the herbicide difenzoquat as recommended reduces the levels of powdery mildew (Erysiphe graminis).

CHEMICAL CONTROL OF PESTS, DISEASES AND WEEDS IN WINTER CEREALS

Pesticide usage in winter cereals

Pesticide use in winter cereals is dependent on the intensity of cropping on the farm and in the surrounding area, cultivations used, cereal cultivar, soil type and location within Great Britain. Not all these factors affect the level of pests, diseases or weeds. Weeds are mainly influenced by the rotation, soil type and cultivation; pests by rotation and location; diseases by cultivar, location and intensity of cropping on the farm and within the surrounding area. Additionally, diseases, weeds and some pests are encouraged by early drilling.

With the increased intensity of winter cereals and the earlier drilling that has been carried out in the 1980s, the use of pesticides, notably herbicides and fungicides, has increased dramatically over the last 20 years. It is difficult to find reliable data to demonstrate in detail this increase in usage but the MAFF surveys in 1977 and 1982 give an indication of the trend (Table 2). Market research and surveys by ADAS indicate that the usage of herbicides and fungicides tended to plateau from 1984 onwards. Insecticide and molluscicide use varies considerably between seasons depending on the mildness of the winter and summer weather for aphids and the wetness of the summer and autumn for slugs. These are the two main pest problems in winter cereals. Unlike herbicides and fungicides, the use of growth regulators in winter cereals has apparently increased since 1984. This reflects recently introduced cultivars being more susceptible to lodging than their predecessors and to the increased importance of grain quality and the rate of harvesting, both of which can be impaired by crop lodging. Evidence that winter barley may respond in yield to the use of chlormequat, even in the absence of lodging, has particularly increased usage.

The increased usage of herbicides is due to the application of soil-applied products primarily for the control of annual grass weeds which are a result of the more intensive growing of winter cereals. Virtually all herbicides are applied as sprays. Most fungicides are foliage-applied sprays. In addition, seed treatments of mercury based compounds are usually used but there has been a significant recent usage of triazoles with or without morpholine based fungicides as seed treatments. Cereal seed is also treated with an insecticide to control soil pests where necessary. Spray applications are used to control aphids and some other pests. Slugs are treated with pellets containing molluscicides and bait and hence their usage is not included in Table 2. Growth regulators are used as foliage-applied sprays. Chlormequat is commonly used at the pseudo-stem erect stage of winter cereals (Zadoks et al, 1974). Plant growth regulators based on 2-chloroethylphosphonic acid are less commonly used and are applied later at the second node detectable to flag leaf ligule visible stage of the crop. Their sequential use is advised where there is a very high risk from crop lodging.

TABLE 2. Usage of pesticide products/ha applied either as sprays or granules to winter wheat and winter barley in England, Wales and Scotland in 1977 and England and Wales in 1982 (Sly, 1981; Sly, 1986).

	Selective Herbicides		Fungicides		Insecticides		Growth regulators	
	Winter Wheat	Winter Barley	Winter Wheat	Winter Barley	Winter Wheat	Winter Barley	Winter Wheat	Winter Barley
1977	1.54	1.21	0.37	0.45	0.48	0.01	0.17	0.00
1982	2.32	1.94	2.02	1.56	0.25	0.12	0.37	0.14

Time of application of pesticides to prevent yield loss in winter cereals

Weeds

The general conclusion from a bibliography of papers on weed competition in all crops compiled by Zimdahl (1980) was that the critical time to control annual weeds in order to prevent yield loss was prior to the period of exponential growth of the crop. This period of growth usually starts in winter cereals in Great Britain at the first node detectable stage. Experimental evidence with annual weeds in this country tends to back this view unless there are exceptional levels of weeds when earlier application may be necessary (Baldwin, 1979; Moss, 1987; Orson and Marshall, 1985). However, in practice, it is unwise to delay weed control until the last moment, particularly if earlier applications of herbicides give economic and effective season long control of weeds. In addition, weeds may be too large to be controlled effectively by herbicides at the time of the pseudo-stem erect stage of the crop or the weather may be unsuitable for optimum activity of herbicides.

Farmers try to apply annual grass-weed herbicides in the autumn and winter. By the late spring, these weeds, with the exception of _Avena_ spp. are too large to control reliably with the current commercially available herbicides. Again with the exception of _Avena_ spp., these weeds are mainly controlled by soil-applied herbicides, which require a period of moisture in the surface layers of the soil. These conditions are less likely in the spring, particularly after mid-February. _Avena_ spp. can be effectively controlled by foliage-applied herbicides in the spring and yield loss prevented, provided that conditions are suitable for the activity of the presently available herbicides before the critical growth stage. These conditions are by no means guaranteed, particularly in the early sown crops, which has again resulted in a significant usage of herbicides to control these weeds in the autumn (Baldwin, 1979). Annual broad-leaved weed control is possible either by autumn or spring application. However, season long control of some species may not be possible from autumn/winter usage of soil or foliage-applied herbicides and of other species from spring usage of foliage-applied herbicides.

It is not possible to control perennial grass weeds selectively in cereals although pre-harvest glyphosate application is often carried out. Perennial broad-leaved weeds do not emerge until advanced stages of the crop and some selective herbicides can reduce populations if they can be applied before the growth stages of the crop when they may cause phytotoxicity. Pre-harvest glyphosate is often used against these weeds.

Diseases

The time of application to prevent yield loss is now reflected in field practice. There is little spraying of foliage-applied fungicides in the autumn and winter unless the weather is exceptionally mild and there is a build up of powdery mildew in barley or yellow rust in wheat. Most of the spraying commences in the spring. Winter barley is usually sprayed with a broad-spectrum fungicide or fungicide mixture at the beginning of spring growth and often a further spray is applied at flag leaf ligule emerged stage. Winter wheat commonly receives two or three sprays. With the recent development of widespread benzimidazol (MBC) resistant _Pseudocercosporella herpotrichoides_ (the eyespot fungus), the 'spray window' has been lengthened as prochloraz (now the most effective fungicide against the disease) can give good control when applied as late as the second to third node detectable crop growth stage. Earlier sprays are not usually necessary except where there is an active yellow rust infestation. Spraying at the flag-leaf ligule emerged stage is the single most important timing for the control of foliage diseases in winter wheat. A further spray may be required at ear fully emerged stage, especially in wet seasons.

Pests

Yield loss from pests is prevented by insecticide application usually when infestations reach action thresholds in the field. Slugs are treated with pellets during the autumn and winter. Insecticide sprays are applied in high risk areas every year and in other areas when the need arises for the control of the aphid vectors of barley yellow dwarf virus. The timing is after the winged invasion but before the population builds up and colonises other plants. This is usually from mid-October to mid-November. _D. coarctata_ is commonly treated by sprays applied at egg hatch from the middle of January or when damage symptoms are seen from late February. Aphids causing direct damage are sprayed when the need arises which is usually in June or July.

Management of chemical pest, disease and weed control

The wide period of time during which herbicides can be applied before yield loss from weeds occurs makes it possible to tank-mix with insecticides, fungicides or growth regulators which have to be applied at more specific times. For instance, in the autumn, a post-emergence spray for weeds can be applied with an insecticide for the control of barley yellow dwarf virus or in the spring, a spray for the control of broad-leaved weeds can be applied with a growth regulator and also a fungicide in barley.

There are some notable exceptions where tank-mixes of pesticides may not provide the ideal means for the optimum or economic control of pests, diseases and weeds. For instance, in Scotland, Wales and the west of England the use of relatively cheap pre-emergence herbicides is often preferred for the control of *Poa* spp. (meadow-grasses). The post-emergence option which can be tank-mixed with an insecticide offers a more expensive alternative. The mixing of an insecticide and grass weed herbicide in the autumn can cause problems where application of the insecticide is deemed to be necessary in mid-October. This may be too early for the optimum control of grass weeds with herbicides such as isoproturon, when the following weather is mild and moist leading to rapid degradation in the soil. *Galium aparine* (cleavers), one of the most common and certainly the most competitive annual broad-leaved weed, usually has to be sprayed in the spring whether or not it has been treated in the autumn. Weather conditions may be too cool for some herbicides at the pseudo-stem erect stage and later spraying may be necessary to achieve optimum control, particularly in early-drilled crops. Fortunately, *G. aparine* can be controlled a little later than other annual broad-leaved weeds before yield loss occurs but such a timing may be too late for the safe and effective use of chlormequat (Orson, 1988). Perhaps one of the greatest conflicts in the timing of herbicides, growth regulators and fungicides is where the fungicide is being applied for the control of eyespot in winter wheat. In terms of the rational use of fungicides, the optimum time for the control of MBC resistant strains of *P. herpotrichoides* and for the first application against some leaf diseases is often at a later time than for the application of herbicides to prevent yield loss from annual broad-leaved weeds, with the possible exception of *G. aparine*, and is too late for the safe and effective use of chlormequat.

There are sometimes other problems with the use of tank-mixes. The addition of some insecticides to isoproturon has occasionally predisposed the crop to frost scorch. The addition of mecoprop further increases this risk. One of the most common tank-mixes used in the spring is mecoprop salt for the control of broad-leaved weeds and chlormequat. On occasions, the addition of chlormequat reduces the efficacy of mecoprop on *G. aparine* (Sansome, 1989).

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