Session 7A

Pesticide Regulation in the EC - The Current Status

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THE EUROPEAN COMMUNITIES REGULATORY REGIME FOR PESTICIDES: CURRENT STATUS AND CHALLENGES

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ABSTRACT

The background to the development of the Community regime for the regulation of pesticides and the main provisions of the regime, including the approach to the specification of data requirements, are described. The benefits of the new regime to industry and others are highlighted. The need for generic data bases, to facilitate further reductions in the extent of testing required and to serve as a basis for the reevaluation of the proposed decision making criteria, are stressed. An approach, involving use of theoretical considerations for the estimation of residues, to resolve problems associated with the availability of products for minor uses, is proposed. Proposals designed to resolve problems relating to water quality and to update the rules for the classification and labelling of pesticides, are made.

INTRODUCTION

The driving force for the harmonization of pesticide regulation in the European Community (EC) arose from differences in the data requirements of the various Member States and differences in the methodologies accepted by them for the generation of data, resulting in very significant additional costs for industry in generating data to address issues that often had already been fully investigated. The additional data thus generated added little to knowledge as to the fate, behaviour and impact of pesticides, while the costs arising necessarily were passed on, ultimately to consumers. Differences in approach to the interpretation of data and in risk assessment (Clegg, 1990) caused grave concern, added significantly to costs, resulted in different decisions being made, and served to increase the growing scepticism with which science, scientists and regulatory regimes are regarded.

The key objectives of the Community in developing its new regulatory regime were, the harmonization of procedures and requirements, the removal of technical barriers to trade and the achievement of a very high level of protection for man, animals and the environment. The basic approach was to enshrine current scientific and technical knowledge and good scientific judgement as the basis for decision making, thereby marginalizing political considerations and influences.

The regime, now largely in place, provides a harmonized basis for the authorization of pesticides that are plant protection products (Council Directive 91/414/EEC), and a harmonized regime relating to pesticide residues in agricultural produce (Council Directives 76/895/EEC, 86/362/EEC, 86/363/EEC, 90/642/EEC and 91/132/EEC). Other elements of the regime already in place include a framework for the prohibition of the marketing and use of particular plant protection products on the grounds of unacceptable impact on human health or the environment (Council Directive 79/117/EEC), and detailed rules for the classification of products as to hazard and for their packaging and labelling (Council Directive 78/631/EEC). The final key element of the Community regime, on which discussions will commence in the very near future, is that relating to the authorization of biocides. Biocides include pesticides, other than plant protection products as well as disinfectants and preservatives.

Separate provisions and rules, which have an important bearing on the regulation of pesticides in the Community, include those concerning the import and export of prohibited or restricted chemicals (Council Regulation 1734/88), those relating to Good Laboratory Practice (GLP) (Council Directive 87/18/EEC), those concerning protection of workers (Council Directives 80/1107/EEC and 90/394/EEC), provisions relating to the protection of vertebrate animals from unnecessary suffering and pain (Council Directive 86/609/EEC), procedures and rules relating to the marketing and use of genetically modified organisms (Council Directive 90/220/EEC), rules relating to freedom to information on the environment (Council Directive 90/313/EEC), and provisions relating to the quality of water, including drinking water (Council Directives 75/440/EEC and 80/778/EEC).

THE AUTHORIZATION OF PLANT PROTECTION PRODUCTS

Main features

The main features of the Community regime have been reviewed on a number of occasions (Mortensen, 1990; Thomas, 1990; Petzold, 1991; Tooby, 1991; Lynch, 1992). In summary, the regulatory system adopted is a two stage process, involving approval of active substances at Community level and authorization of preparations for specified uses at national level in accordance with agreed criteria - the *Uniform Principles* (Commission of the European Communities, 1993). Provision was made for the review of active substances contained in preparations on the market on, or before, 25 July 1993, over a 10 year period, Member States being free to authorize products containing such substances in accordance with national rules as to data requirements and Community decision making rules, pending such review. Prior to the approval at Community level of new active substances, provision exists for the authorization by Member States of preparations containing them, for provisional periods.

The provisions requiring data generated elsewhere to be accepted where relevant agricultural, plant health and environmental conditions are comparable, and those requiring the mutual recognition of authorizations granted in other Member States where conditions are comparable, for preparations containing active substances approved at Community level, are central features of the regime.

Data requirements

The data requirements for active substances are specified in Annex II to the Directive, while those for preparations are specified in Annex III. The Annexes contained in the Directive as adopted, consist simply of lists of headings. They are being revised to provide clear guidance as to the nature of the studies required, the circumstances under which particular studies are required and the methodologies to be used in generating data. In the interests of facilitating the operation of arrangements relating to the mutual recognition of data and authorizations, the test guidelines to be used for individual tests and studies will be specified. The guidelines thus specified will be restricted to appropriate internationally agreed and validated test guidelines.

In the field of toxicology, it is likely that toxicokinetic data will be systematically required. In the case of long term toxicity and carcinogenicity studies, it is likely that it will be specified that the doses tested, be selected on the basis of the results of short-term testing and the level of possible human exposure, and where available at the time of planning the studies concerned, on the basis of metabolism and toxicokinetic data, such that at the highest dose, definite but minimal signs of toxicity are elicited (*viz* slight depression in body weight gain), without causing tissue necrosis or metabolic saturation and, without altering normal lifespan due to effects other than tumours. Higher doses, causing excessive toxicity will not be considered relevant to evaluations to be made. The need, on a case by case basis, for mechanistic studies to elucidate possible mechanisms of toxic action, is likely to be highlighted (Lynch, 1993).

The approach being taken, in specifying the programme of studies to be undertaken, involves a stepwise or sequential approach (tiered) to both the generation of data and to its evaluation, the results of basic tests or studies being used to determine the need for further testing. In the case of ecotoxicology, the approach likely to be adopted involves both exposure and toxicity considerations in determining the need for higher tier testing. Where feasible, testing is to be limited to that with the active substance, where the data thus generated is satisfactory, thereby precluding the need for testing of the various preparations containing the active substance. Similarly, where testing of formulations is necessary, to the extent that it is reasonable to do so, provision is being made for extrapolation from one formulation to other similar formulations. Recently compiled generic data bases relating to aquatic species and impact on honey bees, demonstrating the extent to which such extrapolations are reasonable (Gould 1992; Schmuck *et al.*, 1993), if complimented by similar data bases relating to other species (*e.g.* terrestrial species), will permit the potential for such extrapolation to be maximized, thereby facilitating further reductions in costs.

Those elements of the Annexes dealing with GLP and specifying data requirements relating to efficacy testing have been revised (Commission Directive 93/71/EEC). Testing in accordance with GLP requirements has been limited to those tests and studies, whether conducted in the field or laboratory, which concern human, animal or environmental safety. A separate but analogous regime, but which is less onerous in terms of inspection and audit requirements, has been introduced for other tests. It is anticipated that the revision of the remaining elements of the Annexes will be completed before the end of the year. In so far as the requirements are similar and it is reasonable to do so, the revision of Parts A of the Annexes, dealing with Chemical substances and preparations, and Parts B dealing with micro-organisms and viruses, will be completed at the same time.

Minor uses and extensions in use

The impact of product liability provisions on industry is such that few if any new products will be developed, or few existing products will be defended, for minor uses, because of the limited size of the market for such plant protection products, the often high value of the crops concerned, and the size of claims awarded by the courts. It is likely that, for the future, such commercial considerations will result in industry limiting applications made for the authorization of plant protection products, to major uses or potential major uses. As a result, farmers and growers will undoubtedly face increasing difficulties in obtaining authorized products for use in many situations, and could face serious financial losses.

The provisions of the Directive relating to extensions in the field of use of authorized products, provide a rational and elegant basis for resolving the problem, in so far as authorized products, containing active substances approved at Community level, are concerned. Application for such extensions can be made by official or scientific bodies involved in agricultural activities, professional agricultural organizations, or professional users of plant protection products. Where it is in the public interest to do so, the Member States are obliged to grant extensions sought, where the requirements of the Directive relating to human and animal health and influence on the environment are satisfied. Extensions in the field of use of authorized products are to be granted without any detailed consideration of the performance of the products for the additional uses proposed - no formal efficacy data package is required.

Under the terms of the Directive, the nature and extent of the documentation to be provided in support of applications for extensions in the field of use of authorised products, are left to the discretion of the Member States. It can be anticipated, that in most cases, there will be no additional studies required in the fields of toxicology, environmental fate and behaviour or environmental impact. In some circumstances modelling (calculations) to provide estimates as to the levels of operator exposure likely to arise and to provide estimates of the predicted environmental concentrations for soil (PEC_S), surface water (PEC_{SW}) and ground water (PEC_{GW}) (Lynch 1993), might be required. While the rules relating to the extrapolation of data as to residues in treated crops, to other similar crops, may, in some circumstances, obviate the need for the generation of data concerning residue patterns, the need for additional information and data on residues will nevertheless frequently arise. It is possible, that on the basis of theoretical considerations as to the maximum levels likely to occur on treated crops (Bates, 1990), available information as to residue pattern in other crops and their fate, and consideration of the dietary significance of the residues concerned, the extent of the data required could be minimized.

Such an approach, if adopted by the relevant regulatory authorities in the Member States, would facilitate access by farmers and growers to products necessary for economic production of produce of the required quality. To be of practical value, it will be necessary that arrangements also be made for the establishment of Community maximum residue limits (MRLs) for the commodities concerned, on the basis of such a reduced data package. Of course, farmers and growers using products on the basis of extensions in use granted, will do so without the protection afforded by the normal product liability arrangements, unless, in response to requests that must be made by the regulatory authority concerned, the manufacturer agrees to add the additional use or uses, to the existing label recommendations.

Implications as to cost and other benefits

When fully operational, the new regime will provide significant savings to both industry and governments, as a result of the rationalization of the required testing programmes, the elimination of unnecessary duplicative testing, the standardization of test guidelines to be used, the standardization of formats for the preparation of applications and supporting documentation, the centralization of much of the evaluative and decision making process and, where conditions are comparable, the elimination of duplicate assessments. However, the elimination of early access to the market, as has been possible under national arrangements operated heretofore in Member States such as Belgium, France, Ireland and the United Kingdom, will result in an increase in the time period necessary to recover costs, offsetting to at least a limited extent, the financial benefits for industry arising from the new regime.

Further benefits to industry, as well as to other interested parties, will accrue from the greater transparency inherent in the new system, the existence of much improved data bases for decision making, and consistency in decision making based on good science. The marginalization of political considerations in the decision making process, will lead to authorizations being attainable in all relevant parts of the community, rather than in just some relevant Member States, as at present. The likely adoption of the Community system by European Free Trade Area (EFTA) countries, and other European countries, will extend the benefits arising, still further.

ISSUES NOT YET RESOLVED

Criteria relating to water quality

The Community regime, in so far as water quality and pesticides are concerned has been established through two separate Directives (Council Directives 75/440/EEC and 80/778/EEC). The former establishes limits for pesticides (total content) in surface water used for abstraction of drinking water at between 1 microgram per litre and 5 micrograms per litre depending on level of treatment. The latter establishes a limit of 0.1 microgram per litre for individual compounds and 0.5 microgram per litre for pesticides in drinking water, regardless of whether the water concerned is from surface or ground sources. The limits, which have been transposed into the national laws of the Member States, are, and continue to be, minimum standards which must be enforced throughout the Community. Neither Directive provides guidance as to how metabolites, degradation and reaction products are to be treated, consequently that is a matter within the competence of individual Member States. The community regime does not include any provision for water quality limits for pesticides with potential to leach to ground water, where the ground water concerned is not intended for abstraction of drinking water.

The Commission, in making its proposal to Council as to the evaluative and decision making criteria to be used by the Member States in authorizing plant protection products, that is for the *Uniform Principles* (Commission of the European Communities, 1993) which will form Annex VI to Directive 91/414/EEC, necessarily had regard to the existing Community regime. In so far as drinking water is concerned, the Commission's proposal goes beyond the existing regime in that it specifies that metabolites, degradation and reaction products as well as active substances, satisfy the 0.1 microgram per litre limit and, further specifies that the limit be satisfied without *special treatment*. With regard to surface water intended for the abstraction of drinking water, the Commission's proposal exactly reflects the *status quo*. In the case of other surface waters, it is proposed that authorizations not be granted where products have *an impact deemed unacceptable on non-target species, including animals, ...* .

The Community regime relating to water quality has been the subject of continuing and sustained criticism (EUREAU, 1991; ECPA, 1992). In so far as pesticides are concerned, the limits established are arbitrary in nature, providing, for some compounds, an inadequate margin of safety for consumers. For most compounds the limits are unnecessarily stringent, and place European agriculture and industry at a competitive disadvantage to other regions of the World. The fundamental problem is that the limits established do not reflect the dose/response relationship of toxic and other responses to biologically active compounds. The Community regime includes aesthetic parameters and reflects the *Precautionary Principle*. The Commission, having recognized that a case exists for the reexamination of the regime, convened a conference, in September 1993, to examine the need for its possible revision. Given the nature and complexity of the issues involved and of the procedures that must be followed, any revision of the regime undertaken, necessarily will take a considerable amount of time before it becomes effective.

In the interest of not further compounding the problems created by the existing water quality regime, the reference to *treatment* should be deleted from point 2.5.1.2 of part C of the Commission's proposal on *Uniform Principles*, as should the reference to metabolites, degradation and reaction products from part C points 2.5.1.2 and 2.5.1.3. Decisions with respect to content of metabolites, degradation and reaction products should be made on the basis of toxicological and ecotoxicological parameters, as suggested hereunder.

While a case can be made for the immediate proroguement of the limits for pesticides, that case is unlikely to be sustained unless, a data base which has been subjected to peer review as to its quality and, which relates to a large number of compounds, agricultural practices, water bodies and aquifers as well as geographical regions, is made available. That data base should demonstrate the extent to which compounds currently used, lead to contamination of water at levels infringing existing limits. During any period of proroguement granted, efforts should be concentrated on developing suitable monitoring and information exchange procedures, including appropriate quality assurance procedures for monitoring data. With a view to facilitating adoption of a scientific approach in the elaboration of a new Community regime relating to water quality, data should be compiled as to the impact of the current water quality regime on competitiveness and on employment levels. The data concerned might be generated by the pesticide industry in cooperation with other relevant organizations, such as water authorities, farming organisations and other sectors of industry including the food industry and should be compiled in accordance with procedures agreed with relevant national and Community agencies. Without such data and information, Council is unlikely to set aside its current policy with respect to water quality which includes as a basic principle reliance on the *Precautionary Principle*.

The revision of the water quality Directives, in so far as pesticides are concerned, should include provision for the establishment of limits on a compound by compound basis, by a Technical Adaptation Committee. The revised Directives should specify the criteria to be used which should reflect those used by WHO in revising its Guideline Values for Drinking Water, and should specify that individual limits be established on the basis of their application to the data contained in the monographs to be published by the Commission following inclusion of individual active substances in Annex I to Directive 91/414/EEC and any available monitoring data meeting specified criteria as to quality assurance. Pending the availability of such monographs, limits could be established on the basis of relevant reports of the Scientific Committee for Pesticides, the Monographs produced by the FAO/WHO Joint Meeting on Pesticide Residues (JMPR) and Environmental Health Criteria Documents produced by the International Programme on Chemical Safety (IPCS), as appropriate.

Pending the revision of the water quality Directives and the consequential revision of relevant provisions of the *Uniform Principles*, an interim solution, based on the Guidelines developed by WHO is suggested, an amendment that anticipates, and for its adoption would require, the proroguement of the existing limits for pesticides in the Community water quality regime:

> No authorization shall be granted if the concentration of the active substance and its metabolites, degradation or reaction products included in the residue definition, in water intended for human consumption, as defined by Directive 80/778/EEC of 15 July 1980 relating to the quality of water intended for human consumption, may be expected, to be more than one tenth of the ADI established for the active substance.
>
> No authorization shall be granted if the concentration of the active substance and its metabolites, degradation or reaction products included in the residue definition, which may be expected after use of the plant protection product under the proposed conditions of use, in surface water:
>
> (i) exceeds, where the surface water in or from the area of envisaged use is intended for the abstraction of drinking water, one tenth of the ADI established for the active substance; and
>
> (ii) has an impact deemed unacceptable on non-target species, including animals, according to the relevant requirements provided for in part C point 2.5.2.

Criteria relating to impact on non-target species

The approach adopted by the Commission in making its proposal as to decision making criteria, involved the consideration of acute and repeated dose or chronic toxicity as well as exposure. Where defined ratios as between toxicity and exposure are exceeded, authorizations may only be granted where *it is clearly established through an appropriate risk assessment that under field conditions*, the viability of species concerned is not threatened, or there is no unacceptable impact or other effect on the species concerned, as appropriate. In the absence of data correlating toxicity/exposure ratios derived from laboratory data, with results of testing under field conditions, the Commission necessarily took a conservative approach in elaborating its proposals.

Since the Commission developed its proposal, a generic data base and correlation of aquatic field no-effect concentrations with the results of laboratory testing (acute and long-term), has been compiled (Pflüger, *et al.*, 1993). That data base, provides a clear indication that the toxicity exposure ratios proposed by the Commission for fish and *Daphnia* at 100 for acute exposure and 10 for chronic exposure, are unnecessarily conservative. Similarly, the data base shows that the algal growth inhibition/exposure ratio of 10 proposed, is unnecessarily restrictive. If and when similar generic data bases relating to other effects (*e.g.* toxicity to birds, honeybees and other beneficial arthropods, earthworms, soil micro-organisms) are made available, a basis will exist for the re-examination of the relevant toxicity/exposure ratios proposed by the Commission, and possibly for their revision.

OTHER KEY CONSIDERATIONS

Classification, packaging and labelling

While active substances are classified as to hazard in accordance with the regime developed for all chemical substances (Council Directive 67/548/EEC), formulations are classified in accordance with a separate Directive which provides for a differentiation as between formulations which are solids, liquids or gasses and, provides for toxicological data other than acute toxicity data as well as other relevant information to be taken into account (Council Directive 78/631/EEC). That Directive is in urgent need of up-dating to explicitly address classification and labelling on the basis of the results of chronic toxicity testing and to reflect hazards for the environment. The Commission, supported by a number of Member States, while acknowledging that the regime for pesticides is outmoded, believe that pesticide formulations should be classified in accordance with the regime for general preparations (Council Directive 88/379/EEC). In the case of general preparations, information for their classification is frequently limited, although available for their various components. General preparations are therefore classified on the basis of the intrinsic properties of their constituents and the application of conventional factors, thereby precluding the need for further (unnecessary) testing and permitting an approximation to be made as to the hazards that may arise for man and the environment.

Since in the case of pesticide formulations, the intended use and their manner of use is always known, and assessments, based on full data packages, of potential risks for man, animals and the environment, under practical conditions of use, precede classification and labelling, approximations are not necessary. Were pesticide formulations classified in the same manner as general preparations, many products shown on the basis of detailed risk assessments to present no appreciable or unacceptable risk to human health or the environment, would nevertheless be classified as being carcinogenic, as being toxic for reproduction, or as being dangerous for the environment and be labelled accordingly (Tables 1 & 2).

Clearly, it is not in any ones interest that classifications for pesticides and risk and safety advice on labels exaggerate or misrepresent the hazards arising. It is therefore suggested, that Directive 78/631/EEC be updated as a matter of urgency and that the general preparations Directive not be amended to include pesticide formulations within its scope. Since classifications made are intended to identify hazards arising rather than actual risks, in the amendment of the classification regime for pesticides, classification as to chronic toxicity and environmental effects should be based on the application of a hazard quotient to the exposure level estimated or measured, thereby providing for exposures that may arise as a result of accidental exposure or careless use.

TABLE 1. Classification and labelling of formulations containing active substances classified as being carcinogenic, teratogenic or mutagenic, in accordance with the requirements for general preparations.

Classification of Substance	Concentration Limits for Classification of Preparations as X_n or T[1]	Labelling Required for Preparations that Classify[2,3]
Carcinogen, Category 3	≥ 1%, X_n	R40, S23, S38 or S 51
Mutagen, Category 3	≥ 1%, X_n	R40, S23, S38 or S 51
Teratogen, Category 1	≥ 0.5%, T	R61, S23, S38 or S 51

[1] X_n = Harmful, T = Toxic

[2] R40 = Possible risks of irreversible effects, R61 = May cause harm to the unborn child, S23 = Do not breathe gas/fumes/vapour/spray (to be specified by the manufacturer), S38 = In case of insufficient ventilation, wear suitable respiratory equipment, S51 = Use only in a well ventilated area.

[3] The S-phrases are required for preparations to be sprayed.

TABLE 2. Active substances classified as category 3, carcinogens or mutagens and category 1 teratogens.

Category 3 Carcinogens		Category 3 Mutagens	Category 1 Teratogens
Aminotriazole	Folpet	Benomyl	Warfarin
Atrazine	Isoproturon	Carbendazim	
Captan	Linuron	Phosphamidon	
Chlorothalonil	Propazine	Thiram	
Daminozide	Simazine	Ziram	

Future developments

It is anticipated that, at an early date, the Commission will submit a proposal to Council for the amendment of Directive 91/414/EEC. That proposal, is expected to include detailed requirements relating to formulants and adjuvants and updated explicit rules relating to plant protection products containing or consisting of genetically modified micro-organisms. It is also anticipated that the Commission will, at a future date, submit proposals to Council for a harmonized regime relating to the distribution and use of pesticides, a regime that can be expected to address issues such as the training and certification as to competence of those involved in the distribution and use of pesticides and issues relating to the availability and suitability of protective clothing and equipment.

CONCLUSIONS

While there are many challenges still to be met, the new EC regime provides a rational system for the regulation of pesticides which, when fully operational, will result in significant savings for industry. Through the provision of generic data bases demonstrating the relative toxicities to non-target species of active substances and formulations, the predictive value of laboratory data as to leaching potential to ground water and as to impact on non-target species under field conditions, industry can facilitate the early resolution of many remaining problems.

Reliance on the current Community regime relating to water quality, as proposed by the Commission, constitutes a serious anomaly in the regime, in that it represents a significant departure from the basic principle of decision making on the basis of good scientific judgement. Industry, through provision of an appropriate data base to establish the extent to which the current Community regime is breached (by active substance, region and aquifer), and through provision, in cooperation with other relevant organisations (*e.g.* food industry, water authorities), of data as to the impact of the current water quality regime on competitiveness and on employment levels, could greatly facilitate the adoption of a science based water quality regime.

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PESTICIDE REGULATION IN THE EEC; IMPLEMENTATION IN THE UK

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ABSTRACT

No longer are we discussing **when** will Directive 91/414/EEC, concerning the placing of plant protection products on the market, be implemented. The debate has switched to **how** will it be interpreted and put into operation. There has been a popular misconception outside the regulatory authorities that harmonisation will extend to every aspect of the regulatory process. It was never intended to harmonise all procedures. The very division of labour between the Standing Committee on Plant Health evaluating the active substance and Member States assessing the risk of use of the product is testimony to this. Furthermore, it is unreasonable to expect twelve Member States with widely differing systems to adopt the same procedure over-night. This, of course, presents the applicant with some problems with the such matters as the format of the data submission, the extent of the data required and on what scientific basis have the decisions for further data been based. This paper presents some thoughts on the practical aspects of the application as adopted by the UK registration authorities.

INTRODUCTION

The date for the implementation of the Directive concerning the placing of plant protection products on the market (91/414/EEC) was 25 July 1993. In common with the other Member States, the UK was not in a position to complete the domestic legislation required for implementation on that date. However, by the time that this paper is to be given it is intended to have the necessary Regulations laid before Parliament.

By now each Member State and potential applicants will have been made aware of the contents of the Directive and its Annexes. The main objectives of the Directive are to harmonise the procedures used by Member States to authorise the sale and use of plant protection products; prevent barriers to trade in plant protection products and in plant products; and, most importantly, the risks to health, groundwater and the environment and human and animal health should take priority over improving plant production. The latter point is the most important and not always realised by applicants. In fact it has been the underlying principle of the UK legislation since 1986 (Control of Pesticides Regulations, 1986) and is the point about which there is the most lively debate within the EEC.

In May 1993, the UK Pesticides Safety Directorate held a one day seminar on the implementation of the Directive (Pesticides Safety Directorate, 1993a). It was essential to indicate to the Industry that not all of the structures and provisions had been agreed by the Member States at that time yet there was a need to have in place the domestic legislation to implement it by July. Most importantly the Annexes identifying the data requirements for the active substances and each product containing those substances have not been completed at the time of writing this paper. Also the important Annex VI, the *Uniform Principles*, is still under discussion. From the discussion at this seminar it was clear that the debate had moved on and that representatives from Industry were concerned with the practical issues of implementation rather than the text of the Directive itself. The UK presented an honest picture that essentially it was business as normal with the intention that necessary changes would be introduced in stages as they became known. Clearly some changes were necessary immediately to implement the Directive and these were discussed and now form the basis of the current procedures.

A number of matters of concern have been identified by the Industry but four main items received the greatest attention. These were the Reviews procedure; the data requirements necessary for Annex I listing; the procedures for granting product authorisation which will be enshrined in the Uniform Principles; and the selection of further data by means of trigger values. The Reviews procedure is the subject of another paper at this conference and rightly justifies a separate discussion so it will not be referred to in this paper again. It is the intention of this paper to consider the practical issues of registering active substances and the products containing them as far as the UK is concerned.

It must be recognised that much of the development of procedures will take place only after the experience of assessing several active substances at the Standing Committee on Plant Health (SCPH). In the meantime the priority will be given to developing harmonised decision making procedures. It is inevitable that domestic arrangements will remain in operation until such time as consistent procedures and formats are seen to be necessary or desirable.

In the UK, the registration of crop protection products is handled by the new Pesticides Safety Directorate, an executive Agency of the Ministry of Agriculture, Fisheries and Food. The framework document (Pesticides Safety Directorate, 1993b) and business plan for this Agency clearly identified a number of performance targets which will have to be met in operating the new legislation under the Directive. These have included the need to inform Industry of any changes and agree timetables for their implementation. Also targets have been set for the numbers of units of work to be undertaken each financial year and the expected response time for completing work. Over the next few years clear efficiency gains will be expected which will be quantified in terms of increased numbers of work units completed or decreased times taken to respond. All of these work procedures will have to be undertaken in response to the operation of the Directive.

For at least the next decade the registration procedures will fall into two streams. It must be recognised and, indeed most of the Industry is now aware, that active substances already authorised by a Member State will be evaluated under the National Rules already in operation provided that they cover the principles enshrined in Article 4 (1) (b) (vi) and (v) on safety. The current UK procedures are robust enough to cover the main points in this Article and will remain in force until the active substance is included in the Reviews procedure assessment.

PROCEDURES REQUIRED TO OBTAIN ANNEX I LISTING (Annexes II and III)

Data Requirements

The data required to support an application for Annex I listing fall under a number of headings provided in Annexes II and III of the Directive. Until now the only documents giving any indication of the detailed protocols and the procedures for the selection of further data and decisions to be made have been found in the two reports by Lynch (1992; 1993). More detail will be provided in a series of Commission Directives amending the Annexes to Directive 91/414/EEC. Currently only the introductory sections to both Annexes II and III and the efficacy section of Annex III have been agreed by the SCPH and these have been published in the Official Journal.

Each section has been expanded to give the necessary detail for both the Member State and the applicant to select the most appropriate data to support the application. The UK has been involved in a number of the 5 Member State Expert Groups at which the scientific detail has been discussed. At the next stage the Commission Working Groups discuss the text prior to the SCPH agreeing the document.

The key provisions of the Directive have been reflected in the Annexes and these are to ensure that scientific and technical knowledge are used for the decision making; that risk management is part of the evaluation process; that there is an obligation to ensure that there is a high standard of protection for operators, consumers and the environment; and that there is a real benefit from the use of the plant protection product.

Until the expanded Annexes are published it is not possible to present further detail. For those companies intending to apply for authorisation for a completely new active substance through the SCPH using the UK as rapporteur, the presentation should be the same as that currently required for applications under the National Rules ensuring that the data fall under the headings identified in the current Annexes II and III of 91/414/EEC. It is intended that the data will be evaluated in a similar manner through the Advisory Committee on Pesticides (ACP) and its Subcommittee prior to being considered at the SCPH. Before the end of the year the UK will be publishing a new Control of Pesticides Regulations Handbook giving the procedural requirements and updating the old Working Documents with, where possible, new sections on the data requirements. The data presentation should be no different from that currently in operation.

Some advice to prospective applicants can be offered at this stage. All data packages must be complete and all sections in Annex II and the relevant sections in Annex III must be addressed. Provision has been made in the Annexes for cases to be made if data are irrelevant or inappropriate. The guiding principle should be the presumption that the package must fully support the the intended uses. Therefore, at no stage can preliminary data reports or interim studies be acceptable.

Application and Evaluation Procedure

The procedure to be adopted for new active substances will depend on whether the active substance is already authorised for sale and use elsewhere in the EC and whether the applicant wishes the UK to be rapporteur. For active substances which have no authorisation in the EC and, therefore, require Annex I listing, there will be two main procedural routes from the UK point of view. Firstly, if the applicant wishes the UK to present the evaluation to the SCPH, the new procedures will come into force. The evaluation will be conducted and the evaluation document submitted to the ACP. If the recommendations are acceptable to the ACP and subsequently the six Government Departments responsible for pesticide registration, the evaluation will be submitted to the SCPH. Secondly if the applicant wishes to apply to another Member State, the UK will only assess the data prior to the decision at the SCPH and would not prepare a full evaluation document. The precise details of the format of these documents are to be developed over the next few years.

The UK can be involved at three levels with applications for new active substances. These have been presented in Fig 1.

Figure 1. NEW ACTIVE SUBSTANCE PROCEDURE.

- **ACTIVE SUBSTANCE ALREADY ON MARKET**
  - **National Rules**
- **ACTIVE SUBSTANCE NOT ON MARKET**
  - **UK to seek Annex I listing**
  - **Another Member State to seek Annex I listing; Transitional measures under Article 8.1**

Clearly an application can be made to more than one Member state at the same time. In such a case, the UK will be asking the applicant whether it wishes the UK to proceed as rapporteur. If the answer is that the applicant wishes another Member State to be rapporteur but, nevertheless, wishes the UK to grant a provisional authorisation prior to the decision at the SCPH, under Article 8.1, the UK will evaluate the data and recommend authorisation if appropriate.

The detail of the response time and main steps for both the National Rules and the new procedure are given in Figs 2 and 3.

Figure 2. NATIONAL RULES

- **SIFT - 120 DAYS**
- **APPLICANT CORRECTS/AMENDS APPLICATION**
- **EVALUATION AND COMMITTEE ASSESSMENT AND APPROVAL GRANTED (FOR A MAXIMUM OF 10 YEARS)**

  - 290 DAYS

It is of interest to note that the UK has not received any application for active substances new to the EC into the Committee queue. Effectively this means that work up to at least the February Subcommittee on Pesticides will be under National Rules.

Figure 3. UK PROCEDURE FOR ANNEX I LISTING

- **SIFT - 120 DAYS**
- **INFORM BRUSSELS OF COMPLETENESS OF DATA PACKAGE**
- **APPLICANT AMENDS PACKAGE**
- **EVALUATION AND GRANTING OF APPROVAL (FOR A PERIOD NOT EXCEEDING THREE YEARS)**
  - 290 DAYS
- **PRESENT MONOGRAPH TO STANDING COMMITTEE ON PLANT HEALTH**
- **GRANT PRODUCT APPROVAL(S), AMEND EXISTING TRANSITIONAL APPROVALS AND GRANT FOR 10 YEARS OR REVOKE APPROVALS**

PRODUCT AUTHORISATION

No product authorisation can be carried out under the Directive until the active substance contained within that product has been listed in Annex I. For example, mutual recognition under Article 10, new product authorisation and formulation changes cannot be undertaken.

Product authorisation falls into three main streams. Those active substances not on Annex I but have had a registration within the EC prior to July 1993, will be processed as at present under the National Rules through either the Committee or the Technical Secretariat Stream. For those active substances new to the EC and without Annex I listing, authorisation for three years can be undertaken under the transitional arrangements. After the SCPH has agreed to list the active substance on Annex I, the product will be authorised for a period of up to 10 years.

Once an active substance has been included in Annex I, products containing that active can be authorised in each Member State through a number of procedures. Clearly the procedure of greatest interest to both Industry and the regulatory authorities will be the mutual recognition of data and evaluation for the purposes of gaining authorisation in other Member States. Matters of concern here are how close are the formulation and uses to be to the original to comply with Article 10. As far as the UK is concerned, the uses and the product specification must be identical. An assessment will be made of the supporting data specifying this to validate the procedure. Therefore, there can never be an automatic authorisation. However, it is important to realise that if the uses and specification are identical, authorisation will be recommended by the UK.

The regulatory authorities have some difficulty at present with the requirements under Annex VI. Here reference to such decision making steps as the need to ensure that no unacceptable environmental effects are observed. What is unacceptable to one Member State could be acceptable to another. It must be recognised, therefore, until agreement is reached over a definition of unacceptability, there will be some difficulty with the operation of this provision.

One way forward would be to request from the first Member State the background information on the decisions made to grant authorisation.

The Uniform Principles must be used in conjunction with the relevant Annexes and since neither the data requirements (selection) Annexes nor the Uniform Principles have been agreed and published, it is impossible to develop practical procedures to ensure implementation. Nevertheless, several drafts have been available for some time which suggest that the data requirements put into practice in the UK are not at variance with those required under the Directive. It is with the decision making that the difficulty lies. In addition to the concept of unacceptable effect there are the uses of trigger values to determine further data requirements and possibly risk management. In practice, however, similar values are used by the UK at present in common with many other Member States. The difficulty will be in drawing together the different procedures adopted in each Member State.

Applications requesting changes to use or the formulation will be processed through the Technical Secretariat Stream in much the same way as now. However, some may be so far removed from the original Annex I listing that the SCPH will need to be informed of the change. In any case there will probably be a need to establish new MRL's associated with the new crop. Guidance in this area is still needed. The key could be found in the wording in Annex I associated with the active ingredient listing.

For research and development, the UK will require that all trials should be notified and that permits will have to be issued. This means that the original automatic experimental permit is no longer valid. The Pesticides Safety Directorate have not been able to print new application forms in time for the implementation, so to prevent delay in issuing permits, the old form for automatic experimental permits has been used with some of the sections recognised as being irrelevant.

SELECTION OF FURTHER DATA AND DECISION MAKING

Study protocols can be harmonised and, indeed, there are moves to extend the Internationally accepted protocols to cover all aspects of the data package. Until these are accepted, applicants to the UK will have to justify any study on good scientific grounds. One of the main provisions is that scientific and technical knowledge must be the basis for the decision making. Therefore, provided there are data to support scientific arguments, decisions can be made on risk and the necessary management needed for safe use of a plant protection product.

The area where there will be differences between the Member States is in the interpretation of the data and the action taken. The joint initiative by the Council of Europe and the European and Mediterranean Plant Protection Organisation (CoE/EPPO), sought to rectify some of the problems with the decision making process in the environmental field. The problem with such schemes is that there needs to be a great understanding of the mechanism of action and hense the true biological effect and the actual environmental exposure. Since there are few data on the transport of pesticides in many of the situations encountered within a target zone as well as outside the treated area, precise quantitation of the environmental concentration or the exposure to an organism is far from being precise. Ususally the exposure concentration is estimated using worst case assumptions. Using the precautionary principle decisions based on these assumptions may lead to uses being refused or restricted.

Similarly the decision making steps adopted in Annex VI are based on a similar premise that in the absence on good data, the worst case scenario must be assumed. The Uniform Principles adopts trigger values to move from one level of data requirement to the next. By taking a precautionary view in the absence of data, some very stringent trigger values have appeared. The UK has no problem with this approach in principle provided that the worst case is a realistic one following the label recommendations and that in the absence of sufficient data to relax the trigger value, the decision must err on the side of safety. Here the Industry could assist by publishing and debating the data which they hold themselves and which could be very useful in relaxing the values chosen. At present the discussion continues in Brussels on what are suitable trigger values and such a debate is expected to continue over many years as mechanisms of effect and transport are better estimated and understood..

The issue over the contamination of drinking water, groundwater and surface-water continues and at the time of writing this paper a conference on drinking water is to be held in Brussels. There may be some implications for the decisions to be made in future on assessing risk to water from the use of pesticides. At present within the UK all applications must address the real issue of contamination of water. Any use deemed likely to contaminate drinking water in excess of 0.1μg/l or exceed the Environmental Quality Standard for aquatic organisms will be restricted to ensure compliance.

CONCLUSION

The simplest advice at present for future UK applicants is to continue submitting high quality applications along the lines discussed regularly with Industry. All packages must be complete and supported fully. All remarks and comments must be based on good science and supported by data. In future any changes will be discussed fully with the Industry as soon as practicable.

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IMPLEMENTATION OF THE EC DIRECTIVE IN THE NETHERLANDS

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ABSTRACT

The status of the implementation and some consequences of the Directive 91/414/EEC and of Regulation 3600/92 for the new Pesticides Registration Board and of the Covenant on the implementation of the Multi-Year Protection Plan (MJPG) is described.

INTRODUCTION

The former Commission on Registration of Pesticides (CTB, Commissie Toelating Bestrijdingsmiddelen) has been adapted since the 1 January 1993 to an independent Board on Registration of Pesticides (College Toelating Bestrijdingsmiddelen). This Board has been given the authority to decide on the approval and registrations of individual pesticides, within a framework made up by the responsible Ministries. It is planned that the Board will be privatised to a great extent and that within a short period the registration Board will work on a so-called cost-effective basis. The board is a college of experts and will work with the benefits of the expert advice of governmental institutes.

The following Ministries have worked together in setting up the new Board and in preparing the framework for data requirements, the evaluation and the decision principles for registration:- Ministries of Agriculture, Nature Management and Fisheries; Ministry for Housing, Physical Planning and the Environment; Ministry of Welfare, Health and for Cultural Affairs and the Ministry of Social Affairs and Employment.

A preliminary set of data requirements, evaluation and decision principles has been descried in a Handbook (Haskoning, 1993). The new Board will work according to the principles described in this Handbook which will be updated regularly. The new system is planned to be legally implemented as soon as possible. In the new situation the Board will start evaluations only on a complete file dossier. Sofar in the present concept of the Uniform Principles (UP) the dossier should be complete at the latest at the time of the finalization of the evaluation for the decision-making. We think that a complete dossier at the start of the evaluation will be necessary to avoid long evaluation periods within the registration body. After 8 weeks the applicant will know whether the file for application is found to be complete or not.

The first evaluation period lasts a maximum of 6 months. After this evaluation period additional questions may be put forward to the applicant. In this period the applicant must carry out additional research or send already available data. The second evaluation period will also last for a maximum of 6 months. The tight schedules are necessary to avoid long waits and delays, which were the main problems with the previous systems. It can be concluded that the new Dutch Board on Registrations of Pesticides is aiming to take decisions on applications for registration within the period of one year.

In the present Dutch Pesticide Act it is normal that plant protection products may only be applied in the field of use, indicated on the label. Up to now no special arrangements have been taken to solve the problem of registration of minor uses of pesticides in the Netherlands. Off-label applications are not allowed sofar in the Netherlands.

IMPLEMENTATION OF DIRECTIVE 91/414/EEC

The present bill for implementing the Directive 91/414/EEC in the Dutch Pesticide Act is awaiting approval by parliament. The Dutch Government is aiming to implement this Directive as soon as possible. A further discussion on the implementation of environmental criteria in our Pesticide Act has recently been started. It is necessary to keep our ideas in line with the present draft of the Uniform Principles. Therefore there is an urgent need to make progress in the EC to discuss the UP in the Council and to come to an agreement on the proposals for the UP. At this moment the present draft of the UP shows for many criteria trigger points for negative decisions, which might be followed by so-called disclaimers, by which the applicant might show that under field conditions no unacceptable effects occur. In our view such decision tree systems might work quite well. However in the present situation most of the field testing protocols are lacking. Possible problems or discussions on mutual recognition of applications might be avoided when the Member States register their data on, for instance, toxicity, exposure and their evaluation procedures. By doing so a further harmonisation will be possible in the next few years.

The Dutch authorities have expressed special interest in the subject of the so called test for "alternative" methods of products. This means that before a plant protection product should be authorized a test should be incorporated to check whether alternatives are available to control the pests or diseases without chemicals, such as by physical means or by less harmful methods, for the environment. So far the other Member States seem to be reluctant to take over the Dutch views on this subject.

REGULATION 3600/92

The re-registration process based on Regulation 3600/92 means that the Netherlands will have to evaluate 6 active ingredients per year. The Dutch Authorities have stated their interest in the evaluation of soil disinfectants, because until recently more than 10 million kg of these substances per year were used in the Netherlands. We prefer to evaluate those active ingredients that were recently fully reviewed in the Netherlands. We think that a Member State should preferably evaluate only those substances which are of substantial relevance for that Member State.

We think that there is an urgent need to speed up the simultaneous process of combined harmonization on data requirements (dossiers), on evaluation principles and on decision criteria. By doing so, the missing links can easily be detected. The Netherlands has already expressed their opinion that uniform principles should also apply for placing active ingredients on the positive list.

At the meeting for adopting Regulation 3600/92, the Dutch Authorities have expressed their request to the Commission to create a cost-effective system for the evaluation of the 700 old substances. Recently other Member States have also asked the Commission for financial support for the Rapporteur Member State. However so far no financial regulations have been adopted for the re-registration process. In the Netherlands recently it has been suggested to introduce in our Pesticide Act the possibility of a special fee to allow the Rapporteur Member State to do all the necessary evaluations properly.

Roughly speaking the process of re-registration of pesticides according to Directive 91/414 and Regulation 3600/92, can be visualized as a filter process. The data requirements in Annex II and Annex III of Directive 91/414 can be seen as the filter material. At the end of the filter process there is also a possible "decision valve". This decides whether the substance will be placed on Annex I or not. Depending on the total costs for industry for delivering all relevant data of Annex II and Annex III, presumably half of the substances will not be supported by a full data package and will not pass (completely) through the filtering process. Bearing in mind that a Member State could also claim that its agriculture, plant health and environmental conditions (including ecological vulnerability, as for instance shallow groundwaters) are quite different from the region where the applicant has already obtained full registration of the plant protection product, the ultimate number of active ingredients that will be fully accepted for mutual recognition may be estimated to be less than 50% of the substances of the positive list. From this analysis it is clear that much time and money of industry as well as evaluative bodies can be saved by adopting the data requirements, the evaluation principles and the decision criteria in a simultaneous approach.

MULTI-YEAR CROP PROTECTION PLAN

The Dutch Government, the Agricultural Board, the Dutch Association of Agrochemical Industries (Nefyto), the Dutch Federation of Distributors of Pesticides (RODIS), the Commodity Boards for Vegetables, Fruit, and Ornamental Crops, the Main Commodity Board for Arable Products, the Dutch Plant Breeder Association (NVP), and the Dutch Association for Seeds and Planting Material (NVZP) have, in July 1993, signed a Covenant to agree the following main targets:

a. substantial reduction of the structural dependence on plant protection products;

b. reduction of the volume of plant protection products. (50% reduction for the year 2000 in comparison with the reference (use 1984-1988);

c. reduction of the emission of plant protection products to the environment.

In the agreement it is clear that the agricultural sector should implement the necessary changes in management itself. The parties agreed that inter alia the adverse environmental effects of the use of plant protection products should be eliminated in a regulation programme of re-evaluation of priority substances. In this programme working conditions are also taken into account.

The Covenant should of course remain in accordance with the EC policies. If the EC obligations require amendment of the Covenant these amendments will be implemented without intervention of the parties. If it is the parties' view that no suitable alternative is available for certain applications (from an agricultural or from a public health point of view), or if a ban would result in considerable worsening of working conditions (because intensified use of alternatives poses a workers risk), they may conclude that as an exception and under stringent conditions (e.g. ban in groundwater protection zones or only with use of a prescription system) the registration for this application can be retained. The registrations for which an exception is made will be maintained until the year 2000 at the latest.

The Government will register the approval holders and the distribution points. Parties aim to include all priority substances that are suitable for professional use in agriculture and horticulture in a controlled distribution system (channelling system) (Ministry of Agriculture, Nature Management and Fisheries, 1993).

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THE EC REVIEW REGULATION

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ABSTRACT

One of the main features of the EC Directive 91/414 is the introduction of a Review Programme to cover all the active substances marketed in the Community on 25 July 1993. By definition, these are existing substances; all others are 'new'.

Very simply, the aim of the Programme is to achieve an EC-wide positive listing, known as Annex 1, of all existing active substances whose risks to man and the environment arising from their pesticidal uses are deemed to be "acceptable" following the evaluation of a suitable data package.

The Programme is referred to in the Directive in Article 8 (2), but is described in detail in the Commission Regulation No 3600/92, which was published in February 1993. Details of the Regulation, the way it affects the UK's own Review Programme and some of the major practical difficulties are described below.

ROLE OF THE PESTICIDES SAFETY DIRECTORATE

In Great Britain, the Pesticides Safety Directorate(PSD) exercises control over the registration or approval of agricultural pesticide products through the Food and Environment Protection Act 1985 and the Control of Pesticides Regulations 1986. Equivalent arrangements operate in Northern Ireland. The approval activity can be divided into three categories. Firstly, approvals of new products based on established active substances are issued. Secondly, and just as importantly, the data supporting the introduction of new active substances is assessed so that products containing these active substances can be marketed. Lastly, the Pesticides Safety Directorate has itself been operating a formal Review Programme for established active substances since early 1990. It is important to maintain a balance between these three categories, bearing in mind the demands of industry, the needs of the general public, and PSD's limited resources.

Whatever the mechanisms of the EC Review Programme turn out to be, we will still have the same problem of allocating resources, but on a much larger scale. To some extent, we shall have less control over this balancing act. The EC Programme is quite specific about the number of reviews we must carry out each year and the number to which we must contribute. We have already decided that our existing Programme must be phased out, except with respect to emergency reviews or reviews restricted to national issues.

Another important matter to be resolved is the question of funding for the EC Programme. The UK Programme is financed by a uniform levy on all the holders of approvals, based on their annual turnover.

Can this system be adapted to the EC Programme? What help can be expected from the Commission? To what extent can we charge the UK industry for an EC scheme? These are not just local problems, but could affect the ability of all Member States to play an effective part in fulfilling their obligations under the EC Programme.

EC REGULATION 3600/92-SCOPE, TIMETABLE, AND PROBLEM AREAS

The first stage of the Programme was to decide on a priority listing for all active substances already marketed in the Community. Approximately 700 active substances are involved. Taking into account various factors such as the extent of use and individual Member States own review programmes, a "Top 90" List was drawn up. This list comprises the first set of compounds to be reviewed and was published as part of the Regulation itself in February this year. The intention is that a new list will be published at regular intervals of approximately 12 months. It is estimated that the whole programme will take a minimum of 12 years to complete.

The next step is that of "Notification"; this is the mechanism by which active substances on the first List enter the Programme. First of all, the 'producers' are given 6 months to inform the Commission if they intend to support their active substances in the Programme. 'Producers' are defined as manufacturers within the Community or, where the active substance is manufactured outside the Community, as the representative/agent or importer. This period of Notification ended on the 1 August 1993. Next, Member States are themselves able to act as notifiers with respect to any of the active substances that have not been supported by 'producers'. This facility is presumably available so that Member States can support an active substance considered important for its own national agricultural industry. This second period of notification again lasts for 6 months and consequently ends in February 1994.

When the Commission knows from the Notifications which of the initial 90 active substances will be supported, it will allocate, by means of a further Regulation, the reviews of those substances to individual Member States, known as Rapporteurs. The approvals of products containing active substances not supported by either Member States or producers will be withdrawn. If all 90 compounds are 'entered' into the Programme, the 4 busiest Rapporteurs will be UK, Germany, France, and Italy, each carrying out 12 reviews. The Regulation will also instruct the Notifiers to submit their data packages to the Rapporteurs over a specified period, probably 12 months. Only when the Notification period has elapsed in February 1994, will it be known how many of the first List are to be supported; an estimate might be that only 80 out of the first 90 active substances will remain in the first stage of the Programme.

The timing and identity of the allocation is obviously crucial for each Member State when trying to plan and organise its review work.

If we assume, for example, that the allocation takes place promptly after February 1994, the submission of data to each Rapporteur Member State will take place over the following 12 months. It would be quite possible for all those submissions to be made in the latter part of the period. In the worst possible case all the data might arrive in the last few weeks of the 12 months allowed.

Other factors also make it very difficult to plan ahead. Until we know which active substances we are required to review, we shall have no idea of the size and complexity of the data package, whether more than one notifier is involved, and most importantly when the data are likely to arrive. These are very real practical problems for regulatory authorities.

Finally, the Regulation requires the Rapporteur Member States to evaluate the data and make a report to the Commission. In general, this report is to be made within 12 months of the receipt of the data. Using the timetable outlined already, this would mean reports being made between February 1995 and February 1996.

CONCEPT OF THE CO-RAPPORTEUR

From our UK Programme, Pesticides Safety Directorate are already familiar with the review sequence of data submission, evaluation, followed by a report made to an independent committee. One new concept introduced by the Regulation is that of the "co-rapporteur". This means that the evaluation of data is carried out, not just by the Rapporteur Member State but also with the assistance of other Member States. It is not clear at the moment how this is to be achieved, and a number of questions arise:

i) When will the co-rapporteurs be appointed?

ii) Co-Rapporteurs will be appointed by the Commission, after consultation with Member States but we have not other details of this process.

iii) Very little guidance is available on the number of co-rapporteurs. The Regulation is silent on this, but a Declaration accompanying the Regulation states that "up to 4 experts from other Member States" shall be consulted for each review.

iv) As we understand it, the co-rapporteurs will not necessarily be involved in the evaluation of all the data package, only the key areas. We are not sure how these key areas are to be decided.

This uncertainty makes planning very difficult especially when trying to decide what resources we should make available when acting as co-rapporteurs. For example, for how many active substance reviews should we be expected to act as co-rapporteurs? How much time would we have to spend on these activities?

THE "RESULT" OF THE REVIEW

According to the Regulation (Article 7) there are 4 possible outcomes:

i) To include the active substance in Annex I to the Directive stating the conditions for its inclusion; or

ii) to remove the active substance from the market; or

iii) to suspend the active substance from the market, with the option of reconsidering the inclusion of the active substance in Annex I after the submission of the results of additional trials or of additional information specified in the report; or

iv) to postpone any decision on possible inclusion pending the submission of the results of additional trials or information specified in the report.

The best possible results would be a listing on Annex I. I suggest that this is unlikely in the majority of cases. From our UK experience, we know that the vast majority of older compounds have large gaps in their database, particularly with respect to some areas of ecotoxicology and effects on wildlife. It is also rare for all the crops on the product labels to be supported by comprehensive and up-to-date residue data. Prohibition of the active substance is a relatively rare event and suspension from the market is a technique that we have seldom used.

This means that most of the compounds in the first List will need to be supported by further new data before Annex I listing can be agreed. These new data will also have to be evaluated by the original Rapporteur, but in this case only 9 months is allowed for assessment from receipt of the data. The same options with respect to Annex I listing, suspension, acceptance are available when the report on the new data is made to the Commission.

IMPORTANT AREAS

Notification and re-registration

The Notification or 'entry' form is published as an Annex to the Regulation. Most of the Notification form is straightforward asking for specifications of the active substance, purity, function etc. The crucial information will be derived from paragraph 3 which focuses on the crops and uses that the Notifier wishes to support. The scale of the review will be determined by the scope of the Notification. If, for example, all crops, uses, throughout the Community are notified presumably it will be necessary to review them in the light of the data submitted. Alternatively, a Notification might be very restricted, confining itself to a single formulation and one crop. Quite apart from the fact that as yet we know nothing of company plans in this area, does this mean that all other crops, uses, formulations could be ignored for the purposes of the review? Our interpretation, based on the last paragraph of Article 8 (2) of the Directive suggests otherwise. This paragraph states that after the Annex I listing of an active substance, "Member States shall insure that the relevant authorisations are granted, withdrawn, or varied as appropriate, within a prescribed period".

We believe that this means that Member States must examine all their own products containing the relevant active substance and alter the registrations/authorisations depending on the conditions of the Annex I listing. It is important to realise that this procedure applies to all the active substances reviewed throughout the Community, not just those for which the Member State is rapporteur. In effect, there is a re-registration period for products that follows the Annex I listing of the active substances in those products. At present, we have little idea how much work this will entail. Major factors are likely to be the conditions for inclusion in Annex I, the scope of the original Notification, and the number of products registered. In the UK, for example, we know that there are approximately 1400 products containing active substances in the first priority List.

Two practical questions arise. Firstly, how is the 'prescribed period' of Article 8 (2) to be decided and by whom? The answer will be affected by the balance of activities referred to above. Secondly, should a fee be charged for this re-registration work?

Data Protection and Proprietary Rights

This is a large and complex subject; one example will suffice to show this. Our experience with UK reviews shows that the data submitted for a given active substance frequently comes from several notifying sources. The packages necessarily differ in completeness and quality. The question arises as to what extent we take these relative contributions into account. At present, in the UK, we consider individual packages during a review and, for the usual case of more data being required, set individual 'shopping lists' of requirements depending on the original contribution. This is an extremely complicated and time consuming process.

Our understanding is that the EC Review Programme takes a different approach. Instead of looking at each package separately, all the data will be combined. It would then be possible to "read-across" and create a complete data package for Annex 1 listing. In this scheme, data protection applies when products are re-registered after the listing, not at the review stage. Article 13 of the Directive describes the detailed arrangements for this protection. The key point is that an applicant for product authorisation would have to show access to the data he/she did not possess and which had been deemed to be "critical" for the purpose of the original Listing

This means that, during the review process, an accurate record would have to be compiled of the contribution from each Notifier. Just as importantly, the record would also have to show which contributions are 'critical' for the subsequent Annex I listing. The records of 'critical data' would have to be readily available to all Member States so that any access issues raised at the re-registration phase could be resolved.

SUMMARY

The most important problems affecting the operation of the Review Programme have been described;

i) The size of the Programme

Many registration authorities are already concerned at the large number (approximately 700) of active substances involved. In this context, PSD are aware of the delays already experienced by the EPA in their re-registration programme.

ii) Funding

The cost of a Review Programme in time and money is well known to the UK. The way in which our contribution both as rapporteur and co-rapporteur will be funded has not yet been determined.

iii) Balance of activities

As outlined above, it will still be necessary to apportion our resources between the EC Programme and other registration activities.

For example, although the routine UK reviews will be discontinued following implementation of the EC Programme, we shall still need to deal with the 'rump' of our own Programme and retain the ability to deal with national 'emergency' reviews.

iv) Re-registration and Notification

This remains possibly the most complex area. The scale and complexity of each review is determined, together with the conditions for Annex I, by the nature of the Notification.

The way in which products will be re-registered after Annex 1 listing has not been thoroughly discussed at a practical level.

v) Data Protection

The extent and way in which this is taken into account will profoundly affect the EC Review Programme.

Session 7B

Integrated Crop Production and Crop Protection Systems

Chairman	Professor R D PREW
Session Organiser	Dr M C HEATH
Papers	7B-1 to 7B-7

INTEGRATING CULTURAL AND CHEMICAL WEED CONTROL IN CEREALS

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ABSTRACT

The development of current rotations has been made possible by selective herbicides and chemical fertilisers. The absolute dependence on herbicides of a system of continuous early-sown winter cereals, established by non-plough tillage, has been proved to be unsustainable. It is therefore acknowledged that cultural and chemical control measures need to be integrated. The extent to which cultural control is used in the future will depend not only on the environmental demands on agriculture but also on the application of the scientific knowledge required to ensure that herbicide dose can be manipulated to fully exploit reductions of weed numbers, weed size or weed vigour achieved by cultural means.

INTRODUCTION

Farmers had to rely totally on cultural weed control prior to the advent of selective herbicides. This was by the use of rotation, drilling date and the use of labour and machinery. Despite all these efforts cereals were weedy, particularly in wet summers. A recent survey on organic farming in England and Wales shows how, in the absence of herbicides and some inorganic fertilisers, weeding and feeding crops still dominate decisions on rotations and general agronomy (Yarham & Turner, 1992).

It was the advent of effective herbicides along with inorganic fertilisers that allowed the farmer to replace the role of the traditional rotation (Orson, 1987). It is almost exactly 50 years ago that field trials with MCPA were started. MCPA was effective in controlling the annual broad-leaved weeds then dominant in cereals, such as common poppy (*Papaver rhoeas*) and charlock (*Sinapis arvensis*). Over the next 30 years, the armoury of herbicides for both annual and perennial grass and broad-leaved weeds was virtually completed. This led in the 1970s to more intensive systems where the role of cultural practices was almost entirely replaced by chemical control. This was demonstrated at its most extreme on the heavy lands of Eastern England where the system of continuous early-sown winter cereals, established by minimal tillage, was practised.

However, this system of cereal growing pushed reliance on herbicides to the extreme. Grass weed infestations, particularly black-grass (*Alopecurus myosuroides*), became severe and the early autumn drilling led to a rapid increase in infestations of barren brome (*Bromus sterilis*). Barren brome was, and still is, difficult to control effectively with cereal herbicides (Peters *et al.*, 1993). It was the high infestations of grasses that partly led to the return of the plough in the 1980s. At the same time the increased area of broad-leaved crops, on which effective herbicides could be used to control all annual grass weeds, aided weed control throughout the rotation. The multiple applications of grass weed herbicides that were often employed in the very intensive winter cereal systems of the 1970s and early 1980s, were the probable cause of herbicide resistance in black-grass (Clarke & Moss, 1991).

Effective weed control remains critically important for the yield and quality of individual crops and for sustaining the rotation. However, the current state of the industry demands that all costs are minimised. The cost of weed control is closely inter-linked with cultivation costs and these two items together can amount to over 20% of the total (fixed plus variable) costs for growing winter cereals in Eastern England.

Agriculture, like all industries, also has responsibilities which it has adopted or may be forced to adopt and which extend beyond the business objective of maximising margins. Two examples of this are the ban on straw burning and the concern over pesticide leaching to water. Such factors may have a profound effect on the use of herbicides in the future and have to be considered when developing cropping systems and weed control policies.

There is little doubt that herbicides will play an essential role in cereal growing in the future. The objective must be to find the correct blend of cultural and chemical weed control in order to maximise margins while responding to outside pressures by reducing to a realistic minimum the genuine or perceived impact on the environment. Unfortunately, some of the cultural methods which minimise herbicide use may increase the overall environmental impact of agriculture.

CULTURAL CONTROL OF WEEDS

The cultural control measures, which can be integrated with chemical control in cereals, are:

Rotation
Stubble management
Primary cultivation
Drilling date of autumn- and spring-sown cereals
Cereal species, variety, seed rate, row width and nitrogen rate
Mechanical weed control

Rotation

Rotations that effectively reduce weeds in cereals are those which include one or more of the following features:

a. Temporary grassland, where the soil is undisturbed for two or three years and where weeds are prevented from seeding.
b. Crops which involve a range of drilling and crop cover dates.
c Crops where mechanical weed control is possible.

Individual weed species germinate at different times of the year. Some species, such as knotgrass (*Polygonum aviculare*) germinate in the spring while a few species like black nightshade (*Solanum nigrum*) germinate in the summer (Roberts *et al.*, 1982). Most arable weeds, however, have a more prolonged germination period but with a peak in the autumn or the spring. It is the weed species which germinate shortly after drilling, and before there is a significant crop cover, which will flourish and return copious numbers of viable seed to the soil seedbank. Thus, variation in drilling dates and hence the date of full crop establishment ideally should prevent any particular weed species from achieving dominance.

Most crops grown today are sown either in the autumn or in the early spring. Therefore, the wide variation of drilling dates and crop cover dates required to maximise the benefit of the rotation are not achieved. However, it is recognised that spring crops do reduce the level of autumn germinating grass and broad-leaved weeds. The optimum balance of winter and spring cropping within the rotation to minimise weed problems has yet to be identified.

Row crops offer the most opportunity for mechanical weed control. The bare summer fallow option under the new set-aside scheme will help significantly; if managed correctly, its beneficial effects on weed numbers should be felt throughout the whole rotation (Clarke, 1993).

Stubble management

Early stubble cultivation after harvest has been considered by many in the industry to reduce weed numbers. However, for some important annual grass weeds, for example wild-oats (*Avena fatua)*, black-grass and barren brome, stubble cultivation may not reduce the viable weed seed bank in the soil and in some cases may reduce the loss of weed seeds through predation and other causes.

Primary cultivation

The plough, by inverting the soil and burying seeds, is an aid to weed control. On the other hand, shallow non-inversion tillage is less likely to bury seeds to a depth from which they will not emerge and could also encourage weed germination by physical abrasion. Those weeds favoured by shallow, non-inversion tillage include the mayweeds (*Matricaria* and *Chamomilla* spp.) and cleavers (*Galium aparine*) and small-seeded annual grass weeds such as black-grass and the meadow-grasses (*Poa* spp.)(Cussans *et al.*, 1979).

Certain weed species are favoured by ploughing i.e. they survive this method of cultivation better than other species. The reasons include high innate dormancy, the acquisition over time of a light requirement for germination, lack of germination in the more constant temperatures experienced away from the soil surface and possible dormancy due to lower oxygen and higher carbon dioxide concentrations at depth. Those broad-leaved species favoured by ploughing include common poppy and the cruciferous weeds such as charlock. Wild-oats can survive ploughing more effectively than some grass weeds because of their ability to emerge from depth and that a small proportion of seed can remain dormant for some years and be capable of germinating when returned to the upper layers of the soil by subsequent ploughing.

Drilling date of autumn- and spring-sown cereals

Most autumn-germinating weed species start to germinate prior to the main drilling period of winter cereals. Hence, the earlier the winter cereals are drilled, the more weeds will establish in the crop. Conversely, higher numbers of broad-leaved weeds may establish in the spring of a late-drilled winter cereal crop because of the more open crop canopy. Although, higher numbers of weeds may establish in early rather than very late drilled spring cereals, delaying drilling of spring cereals is not a realistic option economically.

However, in both winter and spring crops, the principle is not as simple as it first appears because the germination period for each species varies from year to year. The distribution of germination of each weed species within that period also varies from year to year. Therefore, drilling on the same dates every year can have a different effect on weed numbers. The variation is determined by the weather conditions during seed formation and after the seed has shed, seed stock and dormancy.

Drilling winter cereals after mid-October will generally result in a lower requirement for fungicides, aphicides and plant growth regulators and in lower weed infestations as well. Late drilling of winter cereals is therefore perceived by some to be an essential element of integrated farming systems, despite the lower yields that may result. Recently introduced winter wheat varieties such as Soissons and Cadenza grow and develop rapidly and should minimise the potential yield losses of winter wheat from later sowing. In practice, this approach may not always reduce weed control costs. For instance, delayed drilling may obviate the need for black-grass control but not necessarily wild-oats. Herbicides such as isoproturon are cheap and will usually give effective control of black-grass while containing wild-oats. Therefore, if low populations of wild-oats are to be contained with herbicides, rather than by roguing, delayed drilling will not bring savings. In addition, with delayed drilling there is an increased risk of frost lift on the lighter soils on exposed sites and of slug damage on heavier soils. On light soils, the adoption of early drilled spring malting barley is usually preferred to late drilled winter barley.

Cereal species, variety, seed rate, row width and nitrogen rate

Cereal species can affect not only when herbicides should be applied but also the dose required to kill weeds. Since winter barley is more competitive than wheat in the spring, autumn applications of herbicides are more likely to provide season long control. In addition, the strong growth of this crop in the autumn may result in the use of a lower dose than that required in winter wheat to provide effective weed control.

Tall-strawed varieties, higher seed rates and narrow row widths all produce crops which can initially compete more successfully with weeds. At present, few farmers take into account the competitiveness of the variety when deciding a weed control strategy with herbicides but as a better understanding of weed/crop competition develops, such factors could be used as part of the decision making process. In the future, electronics may be able to assist in estimating the impact of crop competition by measuring the level of shading of weeds.

Broad-leaved weed species respond differently to nitrogen. For instance in a cereal crop, the growth of cleavers and common chickweed (*Stellaria media*) is encouraged by nitrogen while knotgrass and common field-speedwell (*Veronica persica*) can be reduced in both number and size (Grundy *et al.*, 1992). In addition, it is likely that cleavers are more able to recover from sub-lethal doses of herbicides in soils well supplied with nitrogen.

Mechanical weed control

There is currently a great deal of interest in mechanical weed control in cereals. Research in Europe suggests that it is unlikely to be as effective as chemical weed control, particularly against annual grass weeds, even after many passes through the crop. The way forward must be, in many situations, integrating mechanical control with low rates of herbicides to provide economic weed control with the minimum use of herbicides (Blair & Green, 1993).

There is mixed evidence concerning the benefit of cultivation in the dark. Many weed species require light to optimise germination. The extent of the exposure to light may vary but for some genotypes (stocks) of some species of weeds a mere flash of light is enough to stimulate germination. Some experiments in Europe have shown a worthwhile reduction in weed numbers after cultivation in the dark, sometimes accompanied by a delay in germination, but in others the reduction of emergence has been only 10%.

CHEMICAL WEED CONTROL

Herbicides will remain an essential part of cereal production in the future but their use needs to be minimised to meet the demands of both the farmer and the general public. Much of the reduction can be achieved not by reducing the number of applications to the crop but by using the dose appropriate to the situation rather than that recommended by the manufacturer. The recommended dose of a herbicide is developed to meet registration and legal requirements which may not reflect every situation on the farm. It is, therefore, often possible to reduce doses below those recommended by the manufacturer and still achieve the control required.

The role of cultural control within a given crop rotation must be to minimise herbicide usage while crops are grown by methods that will maximise margins. The objective must be to reduce, in particular, populations of the weed species which are the most expensive or difficult to control by herbicides.

INTEGRATING CHEMICAL AND CULTURAL WEED CONTROL

Cultural control can reduce the level of herbicide use in three ways:

1. Reducing weed numbers to a level where herbicide application is not necessary or where herbicide dose can be reduced.

2. Delaying weed emergence and/or weed establishment and hence reducing the dose of herbicide required.

3. Killing weeds that have already received a low rate of herbicide.

Reducing weed numbers to a level where herbicide application is not necessary or where herbicide dose can be reduced

"Spray or no spray" thresholds can provide long term advantages in terms of increased margins of winter wheat (Proven *et al.*, 1991). However, the decision making process is difficult because an accurate assessment of weed numbers is often required and further complicated by the fact that high weed infestations can result in a lower percentage weed control being achieved by herbicides (Blair, 1993 - personal communication). To capitalise fully on cultural weed control, herbicide dose should be selected on the number of weeds present or expected as well as other factors such as weed growth and weather conditions. Such an approach is not reflected in the "spray or no spray" weed threshold concept. A more pragmatic approach is to have a series of thresholds where the highest dose is used for the control of very high populations of weeds under poor conditions for herbicide activity but with stepped reductions in dose for lower populations or where the state of weed and weather suggest a higher level of herbicide activity. Such an approach will result in reducing the requirement for the very accurate assessment of weed populations. A herbicide will still be applied even where the population is wrongly judged to be below one of the conservatively set thresholds. Treatment will not be required only where a rapid assessment makes it obvious that the weeds do not threaten the financial performance of current or future crops (Orson, 1990). It is the adoption of this "variable response" thresholds technique that will allow the farmer to exploit fully the value of cultural control.

Delaying weed emergence and/or weed establishment and hence reducing the dose of herbicide required

Measures that delay weed emergence and/or weed establishment will result in less competition with the crop and smaller weeds which are often easier to control with herbicides. In addition, small weeds are more susceptible to frost damage in winter cereals.

Killing weeds that have already received a low rate of herbicide

The growth of many weeds can be severely affected by a very small proportion of the recommended dose of a herbicide. This may make them more susceptible to being controlled with the subsequent use of mechanical weeders or by frost. Herbicides used in this technique should be those which, when used at significantly lower than recommended doses, reduce particularly the growth of the weed species more difficult to control by mechanical means (Blair & Green, 1993).

DISCUSSION

Over the last fifty years, the pendulum has swung from weeds being controlled by solely cultural means to almost a complete reliance on herbicides. The system of continuous early-sown winter cereals established by shallow non-inversion tillage ignored all the rules of cultural control and in the end proved not to be sustainable. Now the pendulum has swung back a little towards cultural control. The question is, in the era of lower cereal prices and increased concern for the environment, whether or not there should be greater reliance on cultural measures.

It is worth reminding ourselves that cultural control is not cheap and not always environmentally beneficial. Autumn ploughing can be expensive and release nitrogen and hence increase the risk of nitrate leaching. Delayed sowing of winter cereals reduces the amount of nitrate held by the crop in the winter and also encourages nitrate leaching. Ploughing kills earthworms and predators of aphids. Therefore, judgements will have to be made on what are the environmental priorities.

To exploit fully cultural control, there should be a structured approach to herbicide use. It is suggested in this paper that the "variable response" threshold concept, where each threshold is conservatively set and easily assessed, is an approach that deserves further study. This approach will also be necessary in the future to fully exploit spatial spray application i.e. remote sensing devices which may assess weed numbers and apply the appropriate dose as the sprayer progresses across the field. In the shorter term, the approach can be used in conjunction with sprayers that have been programmed to apply herbicides according to a map of weed populations in the field. Research on this aspect of weed management is currently underway and the knowledge required to make possible this approach should act as a focus for weed research. It is likely that electronics will aid decision making in the future in other ways. For instance, the measurement of the shading of weeds by the crop and the measurement of the moisture status of the weed, both of which will help determine the dose of herbicide required for control.

A major role of cultural control must be to control or reduce the populations of weeds that are difficult or expensive to control with herbicides. The outstanding example in winter cereals is the brome grasses which cannot be controlled reliably with herbicides.

In conclusion, with more scientifically based decision making based on forecasting, information and measurements of the crop and weed, the pendulum may swing further towards cultural control in the future. However, much depends on environmental priorities because there may be conflicts between minimising herbicide use and other environmental objectives. In the context of minimising herbicide use, flexibility in the choice of primary cultivation and drilling date will become more important. There is also a need to improve stubble management practices to ensure that they have specific objectives and the adoption of mechanical control will be possible in specified conditions. However, all these measures need to be fully exploited by integrating them with a sensible and structured approach to when and how much herbicide should be used. This requires more information on weed competition, population dynamics and the activity of herbicides. It is likely that any further reduction in herbicide costs, made possible by cultural control measures, will be due to lower doses being used rather than a reduction in the number of applications.

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INTEGRATING CHEMICAL AND MECHANICAL WEED CONTROL TO REDUCE HERBICIDE USE

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ABSTRACT

Trials at 2 sites were on natural populations of weeds in winter wheat while at a third oats or rape were sown as simulated weeds in spring wheat. Mechanical weeding gave as good control of large *Veronica hederifolia* plants on a clay soil as thifensulfuron-methyl / metsulfuron-methyl mixed + mecoprop-P. The sequence of 20% of label recommended rate of herbicide followed by mechanical weeding gave good control of *Aethusa cynapium*. On a chalk soil, metsulfuron-methyl + mecoprop-P at 5 or 20% of label rate applied on 11 May followed by cultivation at GS32 gave poorer control of *Stellaria media*, *Galium aparine*, *Veronica persica* and *Papaver rhoeas* than the full rate herbicide alone applied on 27 April. Following 20% of label rate of herbicide by cultivation at GS30 improved the control of all species compared with that rate of herbicide alone. On a loam soil, in spring wheat, oat biomass was reduced by imazamethabenz-methyl treatment at less than 20% of label rate when followed by cultivation compared with no cultivation. Rape biomass was also reduced when thifensulfuron-methyl / metsulfuron-methyl (treatment at rates up to10% of label rate) was followed by subsequent cultivation compared to no cultivation. The paper discusses the issues surrounding the adoption of mechanical weeding.

INTRODUCTION

For economic and environmental reasons, particularly the need to reduce the risk of herbicides contaminating ground water, it is desirable to reduce herbicide use in cereals. Mechanical weed control by harrowing has been shown to give acceptable results both in winter wheat (Rasmussen, 1991) and in spring beans (Cook *et al.*, 1993) but is likely to be very dependent upon relative weed and crop size, weather and soil conditions. Combining sub-lethal rates of herbicides with mechanical cultivations has been successful on plants grown in large trays of soil outside (Caseley *et al.*,1993). Increasing the number of passes over a traditional one spray treatment will result in increased mechanisation costs which needs to be recouped from savings in herbicide use. This paper describes limited results from field trials set up in 1993, at three sites, to compare weed control by mechanical cultivation with and without the application of low rates of herbicides. The results are limited to the first year's data prior to harvest.

MATERIALS AND METHODS

The trial site at ADAS Boxworth was on a clay soil and the main weeds were ivy-leaved speedwell (*Veronica hederifolia*) and fool's parsley (*Aethusa cynapium*). Winter wheat (cv. Soissons) was drilled to a depth of 4 cm at 190 kg/ha on 30 October 1992. Plots (15m by 12m) were laid out in three replicate randomised blocks. A mixture of thifensulfuron-methyl / metsulfuron-methyl (applied as 60 g Harmony M /ha) + mecoprop-P (as 2.3l Astix /ha) was applied on 26 March 1993 using a tractor mounted Lely Autoglide Junior sprayer delivering 200 l/ha at 2.1 kPa. Mechanical cultivation was carried out with two passes (back and forth) by an Einböck weeder in the direction of drilling either on 16 April or 4 May. One treatment was cultivated on 26 March prior to an application of 20% herbicide on 16 April. Both the *V. hederifolia* and the *A. cynapium* were large plants with more than 6 expanded leaves when sprayed and would not be categorised as susceptible to this herbicide treatment. Weeds were counted in 10 quadrats ($0.1m^2$) per plot on 7 June 1993. Counts of *A. cynapium* were transformed logarithmically for analysis of variance. The trial site at ADAS High Mowthorpe was on a silty clay loam with flints over chalk soil and the main weeds present were common field speedwell (*V. persica*), cleavers (*Galium aparine*), chickweed (*Stellaria media*) and poppy (*Papaver rhoeas*). Winter wheat (cv. Mercia) was drilled at a depth of 4 cm at 165 kg/ha on 9 October 1992. Plots (6m by 24m) were laid out in three replicate randomised blocks. Metsulfuron-methyl (applied as 30g Ally /ha) + mecoprop-P (as above) was applied either on 27 April or 11 May using a Hardi sprayer delivering 330 l/ha at 2.8 kPa; mechanical cultivations, using a 'Tearaway', followed on either 4 or 24 May respectively. One treatment was made by cultivating on 23 April followed by 20% herbicide on 11 May. Weeds were counted in 5 quadrats ($0.1m^2$) per plot on 9 or 23 June. Data were analysed using analysis of variance. The Long Ashton trial site was on a well drained very fine sandy loam soil. Rape (cv. Bingo) and oats (cv. Valiant) were drilled as simulated weeds just prior to drilling spring wheat (cv. Baldus) on 10 March 1993. The experiment was a split-plot randomised block with four replicates, with harrowing or no harrowing as main plots split for six herbicide doses. Thifensulfuron-methyl / metsulfuron-methyl (as above) or imazamethabenz-methyl (applied as 2 l Dagger /ha) was applied on 27 April 1993 to rape or oats respectively using a handheld sprayer delivering 250 l/ha. Harrowing treatments were done on 5 May 1993 with the Hatzenbichlor harrow comb, once in each direction. The rape and oats both had 2-3 leaves when sprayed. Biomass of rape and oats was measured on 8 June and 1 July respectively. Data were transformed logarithmically for analysis of variance but as non-transformed values are presented in Figures 1 and 2, no error bars are plotted.

RESULTS

At Boxworth, the combination of mechanical cultivation after a 20% dose of thifensulfuron-methyl / metsulfuron-methyl + mecoprop-P gave equivalent control of *A. cynapium* to that given by the full rate herbicide treatment (Table 1). The combination of 20% herbicide followed by cultivation also improved the level of control of *V. hederifolia* compared to the reduced rates of herbicide alone. Cultivation gave good control of *V. hederifolia* but earlier cultivation prior to herbicide treatment resulted in poor control.

TABLE 1. Weed numbers after treatment at Boxworth with thifensulfuron-methyl / metsulfuron-methyl + mecoprop-P, with and without cultivation, (log. transformed data in parenthesis) counted on 7 June 1993.

Treatment	*V. hederifolia* /m^2	*A. cynapium* /m^2
Full rate herbicide mixture	12.3	10.6 (2.16)
5% herbicide mixture	59.3	27.6 (3.34)
20% herbicide mixture	53.0	24.6 (3.11)
5% pre-cultivation at GS30	29.6	26.3 (3.02)
5% pre-cultivation at GS32	28.3	29.6 (3.20)
20% pre-cultivation at GS 30	23.6	6.0 (1.92)
20% pre-cultivation at GS32	25.0	7.6 (2.13)
Cultivation at GS30	18.3	28.3 (3.33)
Cultivation at GS32	7.0	19.6 (2.61)
Cultivation pre-20% herb	81.0	8.6 (2.07)
Untreated	54.8	44.0 (3.67)
SED (22DF)	7.8	(0.638)

At High Mowthorpe, the low rates of metsulfuron-methyl + mecoprop-P applied on 27 April gave good control of *S. media*. Cultivation at GS32, with or without herbicide, did not reduce numbers of *S. media*. Cultivation alone at either GS30 or GS32, controlled *G. aparine* as effectively as full rate herbicide. Full rate herbicide controlled *V. persica* well. Cultivation at GS30, in combination with 20% herbicide, gave 65% control of *V. persica*. Full rate metsulfuron-methyl + mecoprop-P controlled *P. rhoeas*, with the lower rates being slightly less effective. Best *P. rhoeas* control at this site was given by 20% herbicide prior to cultivation at GS30 (Table 2).

The dose response of oats, and rape, to imazamethabenz-methyl and thifensulfuron-methyl / metsulfuron-methyl was significantly altered by the use of harrowing (transformed data not presented). Oat biomass was reduced where the imazamethabenz-methyl treatment was combined with harrowing (Figure 1) compared with the herbicide alone except at the 40% label rate. There was no benefit in increasing the dose above 5%, when followed by cultivation, except at the 40% rate when there was no benefit of cultivation.

Rape biomass was also reduced significantly more when the thifensulfuron-methyl / metsulfuron-methyl treatment was followed by cultivation compared to without subsequent cultivation at rates up to 10% of the label dose (Figure 2).

TABLE 2. Weed numbers per m² after treatment at High Mowthorpe with metsulfuron-methyl + mecoprop-P, with and without additional cultivation, counted on 9 or 23 June 1993.

Treatment	*S. media*		*G. aparine*		*V. persica*		*P. rhoeas*	
	9/6	23/6	9/6	23/6	9/6	23/6	9/6	23/6
Full rate herbicide	0.7	-	7.3	-	2.0	-	3.3	-
5% herbicide	1.3	-	14.0	-	8.0	-	12.7	-
20% herbicide	2.7	-	18.7	-	8.7	-	8.7	-
5% pre- GS30	1.3	-	9.3	-	4.7	-	11.3	-
5% pre- GS32	-	31.3	-	7.3	-	5.3	-	30.7
20% pre- GS30	0.0	-	5.3	-	4.0	-	1.3	-
20% pre- GS32	-	26.0	-	4.0	-	7.3	-	12.7
Cultivation pre- 20%	9.3	-	6.7	-	4.0	-	14.0	-
Cultivation at GS30	14.7	-	8.0	-	8.0	-	37.3	-
Cultivation at GS32	-	24.0	-	4.7	-	11.3	-	14.7
Untreated	22.3	31.0	15.7	14.7	11.5	5.7	47.0	51.4
SED (16DF)	3.15		6.04		4.31		6.46	
SED (8DF)		5.86		5.48		2.76		11.6

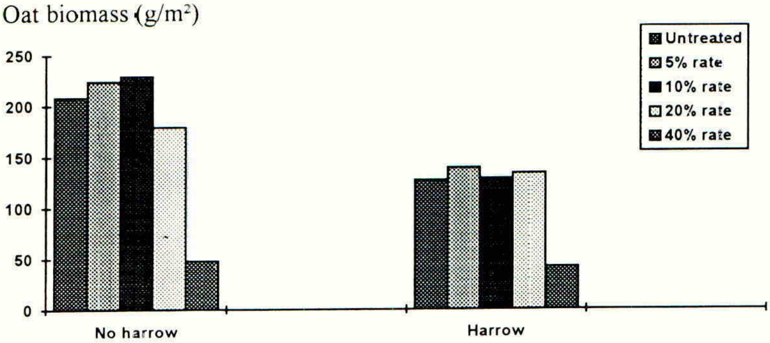

FIGURE 1. Oat biomass after treatment at Long Ashton with imazamethabenz-methyl with or without subsequent harrowing.

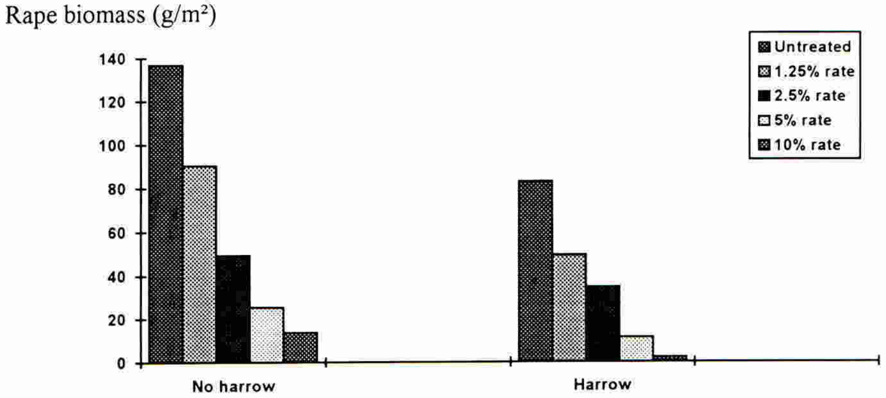

FIGURE 2. Rape biomass after treatment at Long Ashton with thifensulfuron-methyl / metsulfuron-methyl with or without additional harrowing.

DISCUSSION

Two of the sites (Boxworth and High Mowthorpe) had natural weed populations in winter wheat crops and hence the situation may have been very different from the third (Long Ashton) where crops were sown to simulate weeds in a spring wheat crop after failure of winter wheat.

Veronica spp., a fibrous rooted species, occurred on both winter wheat sites. *V. hederifolia* was markedly reduced by cultivation alone at Boxworth to a level comparable with the herbicide mixture at the full rate. Following the herbicide with a cultivation at Boxworth reduced the efficacy of the cultivation, possibly because it stopped the growth of the weed resulting in a smaller target to drag out. Cultivation prior to herbicide treatment was even less effective possibly because the target area for the herbicide was reduced by partial burial of the weed. It would be normal practice to control *V. hederifolia* at an earlier stage than in this experiment. Full rate herbicide gave the best control of *V. persica* at High Mowthorpe. The herbicide applied on 27 April at High Mowthorpe was very active even at the low rates on some species. Treatments applied on 11 May and followed by cultivation at GS32 were ineffective. Control of *A. cynapium* and *P. rhoeas*, both tap rooted weeds, by 20% herbicide followed by cultivation was as good as full rate herbicide at Boxworth and High Mowthorpe respectively. At Long Ashton, even although both the herbicide treatments were very active at low rates, weed control was increased with subsequent cultivation.

The success of combining a herbicide and cultivation treatment for weed control is likely to be very dependent upon weather, soil type and conditions, weed species present, herbicides applied and the weeder used. Of the three sites described here, the benefit of following herbicide treatment with cultivation was greatest on the heavier soil at Boxworth but this could be due to the particular conditions rather than the soil type *per se*. The heavier soil may also anchor the crop better allowing the mechanical weeder to work more aggressively on the shallower rooted weeds. In Denmark, researchers have concentrated on the control of small weeds by cultivating to bury them (Rasmussen, 1992). However, the experiments reported here suggest that there will be an interaction with weed type and in some cases it may be easier to pull out large rather than small weeds, particularly weeds such as *Veronica spp.* and

G. aparine. The timing between spray application and cultivation could be important for some weeds, too long an interval and the weeds might recover. The time interval was much longer at Boxworth than at the other two sites. Cultivation before spray application did not look to be promising at Boxworth but seemed to be more effective at High Mowthorpe and this requires further investigation.

Potential benefits from the use of mechanical weed control without herbicides include the ability to be independent of wind speed which limits spray occasions. In some situations, eg *V. hederifolia* at Boxworth, mechanical cultivation seemed adaquate. Where a low rate of herbicide precedes cultivation, applications are still limited by the speed of the wind but there could be major reductions in pesticide used.

Unless the combined treatment is as effective in controlling weeds as the currently recommended rate of herbicide, it is likely that the weed seed return will be increased even though crop yield may be unaffected. This has implications for weed control elsewhere in the rotation and requires further investigation. However, Clarke *et al.* (1993) have shown the large potential to reduce herbicide dose in its own right. The ability to improve the reliability of a reduced herbicide rate by following it with mechanical weeding or to use the mechanical weeder to allow even lower rates still needs to be confirmed over a range of sites and seasons.

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THE EFFECTS OF AGRONOMIC FACTORS ON COMPETITION BETWEEN CEREALS AND WEEDS; THE IMPLICATIONS IN INTEGRATED CROP PRODUCTION

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ABSTRACT

Three field trials are reported on the effect of fertiliser nitrogen rate on competition between five varieties of spring barley and winter wheat and broad-leaved weeds. Some varieties exhibited earlier ground cover, denser canopy and increased tillering and crop biomass at higher nitrogen rate. In some varieties, however, increased weed competition or crop suppression due to herbicide reduced this effect. Weed levels were highest at high nitrogen rates, but in contrast to this reduced rates of metsulfuron-methyl + mecoprop-P resulted in fewer weeds at higher nitrogen rate compared to lower rate.

INTRODUCTION

A series of trials carried out by SAC since 1989 showed that cereal varieties differ in how they compete with weeds. In some of the trials, a clear negative correlation was seen between crop early ground cover and subsequent broad-leaved weed levels (Richards & Whytock, 1993). It was also shown, in some cases, that there was an interaction between variety competitiveness and herbicide rate, a lower rate being possible with more competitive varieties. These results indicated that by choosing a more competitive variety, it was possible to adopt a lower rate of herbicide in the integrated control of weeds.

But this interaction between variety and weed growth was not clearly seen in every trial and it has become clear that a number of factors may influence how effective, or otherwise, a variety is at suppressing weeds. It appears that in very vigorous crops, a variety is likely to interact and compete with weeds more strongly than in poorer crops. This may lead to the effects on weed levels due to varietal differences only becoming apparent in more vigorous crops.

A number of factors such as soil fertility, light, temperature and water may influence the vigour of crops (Firbank, 1990). Spring barley, for instance, is notoriously intolerant of any soil defects; compaction or very wet weather after sowing may lead to poor growth. Drought may have a similar effect, particularly if there are accompanying soil structural problems that have been limiting to root growth. In winter wheat, time of sowing influences how strongly the crop is growing at the time of weed emergence.

Weed control trials with two rates of nitrogen fertiliser were undertaken in order to evaluate the influence of nitrogen on crop growth and competition between crop and weeds. This has implications to integrated farming where reduced inputs of fertiliser may affect the requirement for herbicide.

METHODS

All three trials were on Boghall farm at SAC Edinburgh (Table 1). They were of standard layout with 2m x 22m plots replicated three times; trial 1 in a partial factorial and trials 2 & 3 in full factorial randomised complete block design. Plots were drilled by Øyjord drill and harvested by Class Compact combine harvester. Assessments of crop and weed biomass were made by cutting plant material, at ground level within a 0.25 m^2 quadrat, from a fixed position in each plot. Tillers were counted, weeds and crop separated and oven dried for 24 hours at 100 degrees C to obtain biomass dry matter yields. Crop 'early ground cover' and 'canopy density' were assessed visually over the whole plot on a 1-9 scale, where 9=early or dense.

Varieties grown are given in the tables of results. In each trial, a range of varieties was selected that exhibit a greatest range of competitiveness with weeds possible in commercially-available varieties. Herbicide used in each trial was a reduced rate of metsulfuron-methyl + mecoprop-P , the full rate being 6 g.AI.ha^{-1}. + 1380 g.AI.ha^{-1} respectively.

In each trial, two nitrogen rates were used being applied as a split application. The higher rate was achieved with an increased rate second application. The high rate was chosen for maximum economic yield taking into account field conditions. The low rate was chosen as one that might be used in a low input system. In the case of spring barley, the low rate selected was one that could be used in order to secure low grain nitrogen and thus a malting premium.

TABLE 1. Trial details.

	Trial 1	Trial 2	Trial 3
Harvest year	1992	1993	1993
Crop	Spring barley	Spring barley	Winter wheat
Previous crop	Spring barley	Winter barley	Winter barley
Date sown	24 March 1992	19 March 1993	19 October 1992
Seed rate	190 kg/ha	190 kg/ha	200 kg/ha
Herbicide rate	high : half rate low : tenth rate	tenth rate	third rate
Herbicide timing	Zc GS 23	Zc GS 24-30	Zc GS 30
Weeds present	*Galeopsis tetrahit* *Polygonum aviculare*	*Stellaria media* *Polygonum aviculare* *Myosotis arvensis* *Sinapsis arvensis* *Poa annua*	*Stellaria media* *Myosotis arvensis* *Galeopsis tetrahit* *Capsella bursa-pastoris* *Papaver rhoeas* *Poa annua*
P_2O_5	70 kg/ha	60 kg/ha	60 kg/ha
K_2O	70 kg/ha	60 kg/ha	60 kg/ha
Date harvested	29 August 1992	2 September 1993	to be harvested

RESULTS

Trial 1 (spring barley 1992)

In each variety, at low rate herbicide, early ground cover was increased with increased nitrogen rate, particularly Shirley, Osprey and Blenheim (Table 2). A similar effect was seen on canopy density. Early ground cover and canopy density varied between varieties, but there was no consistent relationship between these characters in varieties and subsequent weed development (Table 2). Weed ground cover % with low rate herbicide was reduced with increased nitrogen rate. All varieties responded in grain yield to higher nitrogen rate; Tyne was most responsive and Blenheim and Shirley were least responsive (Table 2). At low nitrogen and low herbicide Derkado was the highest yielding variety.

TABLE 2. Trial 1 - Spring barley early ground cover, canopy density, weed ground cover %, grain yield and '000 grain weight..

Variety	Nitrogen	Herbicide	Early ground cover Zc 24	Canopy density Zc 59	Weeds (%)	Yield of grain (t/ha)	'000 grain weight (g)
Shirley	70 kg/ha	low	8.0	7.3	4.3	4.72	46.2
	120 kg/ha	low	9.0	9.0	0.3	5.38	47.7
	120 kg/ha	high	8.7	8.7	0	5.50	47.4
Osprey	70 kg/ha	low	6.7	7.0	3.3	4.48	47.3
	120 kg/ha	low	8.0	8.3	1.0	5.50	50.0
	120 kg/ha	high	8.3	8.7	0	5.55	49.9
Derkado	70 kg/ha	low	7.0	8.0	7.7	5.09	48.7
	120 kg/ha	low	7.3	8.7	3.0	6.01	50.6
	120 kg/ha	high	7.0	9.0	0	6.38	50.6
Blenheim	70 kg/ha	low	5.0	6.7	4.7	4.56	49.2
	120 kg/ha	low	6.3	8.0	0.7	5.07	49.2
	120 kg/ha	high	6.0	7.7	0	5.24	51.4
Tyne	70 kg/ha	low	7.0	5.7	6.3	4.66	40.0
	120 kg/ha	low	7.3	7.3	2.0	6.24	43.4
	120 kg/ha	high	7.3	7.7	0	5.90	41.7
SED			0.67	0.45	1.93	0.19	-

<u>Trial 2 (spring barley 1993)</u>

Early ground cover of Osprey and Felicie and canopy density of Osprey, Felicie and Derkado were significantly higher than the other varieties. Crop height was significantly affected by variety and nitrogen. Osprey and Felicie responded to increased nitrogen rate with increased early ground cover and canopy density, this was not the case with Tyne and Brewster. There was no significant effect of these characters in varieties on weed ground cover % that developed in the crop (Table 3). Weed d.m. tended to increase with increased nitrogen rate in plots untreated with herbicide. In contrast, when treated with herbicide, weed infestation tended to be lower with increased nitrogen rate. This effect was not attributable to any effect of nitrogen on variety vigour.

Crop tiller number and biomass responded to increased nitrogen application, particularly with Tyne and Brewster. This effect occurred regardless of whether herbicide had been applied or not although with Derkado there was a negative effect following herbicide treatment indicating a possible crop tolerance problem with this variety. Brewster was the highest yielding variety and Tyne the most responsive to increased nitrogen. Derkado was the least responsive which was possibly due to herbicide intolerance at the higher nitrogen rate. With low fertiliser and zero herbicide input Tyne was the highest yielding variety.

<u>Trial 3 (winter wheat 1993)</u>

Spark and Hunter, averaged over treatments, had significantly poorer early ground cover than the other varieties. There was no response of early ground cover to increased nitrogen rate because this

TABLE 3. Trial 2 - Spring barley early ground cover, canopy growth and development, weed ground cover %, grain yield and components of yield.

Variety	Nitrogen	Herbicide	Early ground cover Zc 24	Canopy density Zc 50	Height (cm)	Weeds (%)	Tiller (no/m^2)	Response to N	Crop d.m. (g/m^2)	Response to N	Grains per ear	Weed d.m. (g/m^2)	Grain yield (t/ha)
Osprey	80 kg/ha	untreated	8.0	7.0	79	8.7	465		548		24.3	5.5	4.3
	80 kg/ha	treated	7.3	6.3	83	6.7	504		577		24.0	2.1	4.0
	120 kg/ha	untreated	8.0	8.3	90	9.6	519	59	628	80	23.7	13.6	4.9
	120 kg/ha	treated	8.3	9.0	93	9.0	535	31	636	59	24.0	2.8	5.5
Felicie	80 kg/ha	untreated	6.0	6.0	70	9.0	461		441		22.0	4.8	3.4
	80 kg/ha	treated	7.7	6.7	70	8.1	493		512		20.0	28.4	3.4
	120 kg/ha	untreated	8.3	7.7	84	11.0	577	116	616	175	21.3	9.3	4.3
	120 kg/ha	treated	8.3	7.7	83	10.6	516	23	577	65	20.3	7.5	4.4
Derkado	80 kg/ha	untreated	6.7	6.7	60	9.7	437		396		21.3	23.2	3.5
	80 kg/ha	treated	7	7.0	63	7.2	552		515		20.3	4.9	4.4
	120 kg/ha	untreated	6.3	8.3	66	11.1	567	130	539	143	20.7	17.1	4.6
	120 kg/ha	treated	6	8.3	70	8.7	497	-55	489	-26	22.7	14.8	4.4
Tyne	80 kg/ha	untreated	6	5.7	67	7.0	483		436		21.7	5.1	4.5
	80 kg/ha	treated	6	5.7	64	7.9	441		429		22.3	12.9	4.2
	120 kg/ha	untreated	7.3	7.0	72	8.8	661	178	660	224	22.3	4.3	5.5
	120 kg/ha	treated	6.3	7.3	69	8.2	668	227	672	243	21.0	5.1	4.8
Brewster	80 kg/ha	untreated	5.0	4.7	53	9.4	514		383		23.0	8.9	4.2
	80 kg/ha	treated	6.0	4.7	50	5.3	424		341		23.7	6.7	4.2
	120 kg/ha	untreated	6.3	7.7	57	11.1	672	158	563	180	23.7	15.6	5.2
	120 kg/ha	treated	5.7	7.7	59	8.5	680	236	576	235	22.7	3.9	5.5
SED	between variety means		0.49***	0.36***	1.93***	0.61	35.89		42.26*		0.8***	4.88	0.07**
SED	between nitrogen means		0.31	0.05***	1.22***	0.24***	22.70***		26.73***		0.25	3.09	0.03***
SED	between herbicide means		0.31	0.05	1.22	0.24**	22.70		26.73		0.25	3.09	0.03
SED	between all comparisons		0.98	0.73	3.87	2.43	71.80		84.51		1.6	9.76	0.27

* denotes significance at 5% level

** denotes significance at 1% level

*** denotes significance at 0.1% level

TABLE 4. Trial 3 - Winter wheat early ground cover, canopy growth and development and weed ground cover %.

Variety	Nitrogen	Herbicide	Early ground cover Zc 23	Canopy density Zc 57	Height (cm)	Weeds (%)	Tiller (no/m^2)	Re-sponse to N	Crop d.m. (g/m^2)	Re-sponse to N	Weed d.m. (g/m^2)
Brigadier	140 kg/ha	untreated	8.3	6.3	73	28.0	459		850		107.1
	140 kg/ha	treated	7.7	6.0	73	1.3	539		1068		37.1
	180 kg/ha	untreated	7.3	7.0	79	40.0	531	72	870	20	147.2
	180 kg/ha	treated	7.3	7.7	77	0.5	503	-36	1112	44	20.8
Hereward	140 kg/ha	untreated	7.7	6.3	77	37.3	545		1059		52.0
	140 kg/ha	treated	8.0	6.0	76	1.3	460		977		48.7
	180 kg/ha	untreated	8.7	6.3	80	42.3	579	34	1075	16	70.0
	180 kg/ha	treated	8.0	7.7	82	1.7	597	137	1173	196	20.0
Hunter	140 kg/ha	untreated	7.0	6.3	76	45.3	439		848		123.7
	140 kg/ha	treated	6.7	5.7	79	2.0	560		1162		24.0
	180 kg/ha	untreated	7.0	8.3	84	40.3	569	130	1110	262	116.4
	180 kg/ha	treated	7.7	8.7	83	1.3	572	12	1166	4	21.9
Riband	140 kg/ha	untreated	8.7	5.0	82	41.3	451		1015		106.8
	140 kg/ha	treated	8.7	6.3	79	1.0	424		1026		36.5
	180 kg/ha	untreated	9.0	7.0	85	37.7	476	25	984	-31	111.7
	180 kg/ha	treated	7.7	8.0	86	1.0	503	79	1113	87	38.3
Spark	140 kg/ha	untreated	7.3	5.0	82	38.0	665		986		108.4
	140 kg/ha	treated	6.3	5.7	82	2.7	573		889		56.9
	180 kg/ha	untreated	6.7	6.7	90	42.0	580	-85	933	-53	264.7
	180 kg/ha	treated	7.0	7.7	85	0.4	707	134	1034	145	39.7
SED	between variety means		0.30***	0.41	0.99***	3.44	38.75**		58.04		29.75
SED	between nitrogen means		0.19	0.26***	0.63***	2.18	24.51*		36.71		18.82
SED	between herbicide means		0.19	0.26	0.63	2.18***	24.51		36.71**		18.82***
SED	between all comparisons		0.59	0.82	1.99	6.89	77.51		116.07		59.51

*	denotes significance at 5% level
**	denotes significance at 1% level
***	denotes significance at 0.1% level

character was assessed before the extra nitrogen dressing was applied. Canopy density, that was recorded later, when averaged over the varieties and herbicide treatments responded to increased nitrogen rate. There was no effect of variety on weed ground cover at low nitrogen rate, but at high rate there was a negative correlation between early crop ground cover and weed biomass (Table 4). The reduced rate herbicide application achieved a significant reduction in weed levels.

Weed ground cover and d.m. following treatment with reduced rate herbicide tended to be lower with increased nitrogen rate. In the absence of herbicide weed density increased with increased nitrogen rate. Tiller number significantly increased with increased nitrogen rate averaged over varieties, although the tiller number of Spark decreased when untreated with herbicide. Trial still to be harvested.

DISCUSSION

There was no negative correlation between variety early ground cover or canopy density and subsequent weed ground cover, as has been seen in previous trials (Richards & Whytock, 1993). It is thought that this was due to seasonal factors. In 1992, growth of crop and weeds was reduced by dry weather and moisture shortage; in 1993, cold wet weather led to late sowing and slow growth. It is thought that these conditions led to reduced competition between crop and weeds, causing any differences between varieties to be insignificant. Differences between varieties in their suppressing effect on weeds tend to be greatest in most vigorous crops.

In each trial, the full rate of fertiliser nitrogen led to increased early ground cover and canopy density of most varieties. Crop tillering and biomass, measured in trials 2 & 3, increased in response to nitrogen when treated with herbicide. In the absence of herbicide the increased weed growth resulting from the higher nitrogen rate reversed this effect in some varieties, depending on their ability to compete. In the spring barley trials there was a variable yield response of varieties to increased nitrogen. In the case of Derkado in 1993, there was a negative response of biomass and tiller number and zero yield response to increased nitrogen, when treated with herbicide. This indicates a possible crop tolerance problem with this variety at full rate nitrogen, but not at reduced rate.

There was a trend across the three trials in the effect of nitrogen rate on weed control with the reduced rates of herbicide. When no herbicide was used increased, nitrogen application led to increased weed ground cover and biomass with most varieties. However, where herbicide was used there was an opposite trend, weed levels tending to be lower with full nitrogen rate. This has implications for integrated farming where reduced nitrogen rates may lead to poorer control with reduced rates of herbicide.

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THE USE OF CULTIVAR, CROP SEED RATE AND NITROGEN LEVEL FOR THE SUPPRESSION OF WEEDS IN WINTER WHEAT

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ABSTRACT

An integrated approach to weed management was investigated, at one site in 1992, involving the use of different cultivars, seed rates and nitrogen regimes. Maris Huntsman (traditional long-strawed) was significantly more effective that Mercia (modern semi-dwarf) in suppressing above-ground weed dry weight throughout the experiment; increasing nitrogen from 40 to 160kg/ha reduced weed dry weight, weed density and the number of weed species. The suppressive effect of increasing crop seed rate from 250-450/m^2 was observed only at the final weed harvest when a number of treatment interactions also became evident. Individual weed species displayed differing levels of response to cultivar, crop seed rate and nitrogen, the results suggesting that such an integrated approach may afford opportunities for the suppression of weed infestations.

INTRODUCTION

Exploitation of crop competitiveness may be used to manipulate the weed population and thereby provide an alternative weed control strategy. It has been suggested that the choice of highly competitive cultivars could enable a reduction in herbicide usage (Christensen *et al*., 1990). Similar recommendations regarding the use of crop competition as an aid to herbicide efficacy have been made by Richards (1989), Courtney *et al*.(1988) and Easson and Courtney (1989). It is generally recognised that short-strawed cultivars may be at a competitive disadvantage with tall vigorous weeds (Fryer, 1979) and, conversely, long-strawed cultivars may do much to suppress weed growth. Similarly, crop seed rates above the standard rate have been shown to reduce the biomass of broad-leaved weeds and increase grain yields in both organic trials (Samuel and Guest, 1990) and conventionally grown winter wheat (Andersson, 1986). Reductions in nitrogen application rate may influence the composition of a weed

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population (Pysek and Leps, 1991) and recent indications that such reductions may be required (eg. nitrate sensitive areas) necessitates the consideration of this factor. The experiment described here commenced in October 1991, to investigate the relative ability of integrating winter wheat cultivar, crop seed rate and fertiliser to suppress a weed infestation and to study changes in the weed species composition resulting from the treatments.

MATERIALS AND METHODS

The experiment was carried out on the University farm at Sonning near Reading, using a natural weed infestation with treatments replicated four times and arranged in a randomised block design. Plots were 1.8m wide x 3m long and sown using an Øyjord seed drill on 24 October 1991. Treatments consisted of two winter wheat cultivars (Mercia and Maris Huntsman), three sowing densities (250, 350 and 450 seed/m^2) and three rates of nitrogen fertiliser applied (0, 40 and 160 kgN/ha) in a factorial structure. Maris Huntsman is a relatively long-strawed variety and Mercia a modern semi-dwarf. Nitrogen was applied as a split dressing of 2x80 kgN/ha for the highest nitrogen rate plots on 1 April and 10 April. A single application for the 40 kgN/ha treatments was made on 10 April. Signs of mildew made it necessary to use a fenpropimorph fungicide on 10 April and 20 May. Samples of above-ground weed material (0.1m^2) were collected at regular intervals throughout the season from outside the central 1.0m^2 area reserved for crop harvesting. Samples were separated into species, counted and dried, with the final harvest taken on 27 July to coincide with the main crop harvest.

RESULTS

Total weed density and above-ground dry weight

Total weed numbers responded negatively to increasing nitrogen availability ($P<0.001$). However, neither crop seed rate nor cultivar had any significant suppressive effects on weed density at the 5% level (Table 1). The rate of applied nitrogen had a highly significant effect on weed biomass ($P<0.001$), with the 160 kgN/ha plots yielding consistently less above-ground weed dry matter than the 0 and 40 kgN/ha plots (Table 1).

Plots sown with Maris Huntsman consistently produced less weed dry matter over the course of the study ($P<0.001$, for final harvest), although the suppressive effect of increased crop sowing rate was only observed at final harvest ($P<0.001$, Table 1). There were no interactions noted between treatments until the final harvest, when increasing nitrogen in combination with Maris Huntsman resulted in significantly better weed control than with Mercia ($P<0.01$). Also, where plots had been sown with 350 and 450 seeds/m^2, the application of 160 kgN/ha was highly effective in reducing weed biomass ($P<0.01$).

TABLE 1. Total weed density, above-ground weed dry weight and number of weed species in response to nitrogen, cultivar and crop seed rate on 27 July 1992[a].

Treatment	Weed density (Weeds/m^2)	Above-ground dry weight(g/m^2)[a]	Number of species
kgN/ha			
0	143.2	1.23(20.7)	5.77
40	124.4	0.99(16.3)	4.33
160	36.0	-0.09(7.0)	1.80
SE	15.3	0.09	
P	$p < 0.001$	$p < 0.001$	$p < 0.001$
Cultivar			
Maris Huntsman	98.1	0.50(10.4)	3.48
Mercia	104.3	0.92(19.0)	4.45
SE	10.8	0.07	
P	n/s	$p < 0.001$	$p < 0.05$
Crop seed rate/m^2			
250	119.9	1.05(21.7)	4.46
350	87.2	0.67(14.5)	3.89
450	96.5	0.41(7.8)	3.55
SE	13.2	0.08	
P	n/s	$p < 0.001$	n/s

[a] Dry weights have been $\log_{10}$ transformed for statistical analysis and figures in parentheses refer to untransformed data.

Species composition

The main species observed on the experimental site included *Matricaria recutita* (Scented mayweed), *Stellaria media* (Common chickweed) and *Polygonum aviculare* (Knotgrass). The less prominent species were grouped together and termed as "other". "Other" species consisted mainly of *Chenopodium album* (Fat-hen), *Capsella bursa-pastoris* (Shepherd's-purse), *Papaver rhoeas* (Common poppy) and *Poa annua* (Annual meadow-grass). The total number of weed species present responded negatively to increased nitrogen ($P < 0.001$). A less diverse weed community was evident on plots sown with Maris Huntsman, this trend increased in significance over time ($P < 0.001$ by final harvest). Increasing crop density also reduced the number of species present albeit only statistically significant at the penultimate harvest date ($P < 0.05$, data not shown).

Total above-ground dry weights/m^2 for *P. aviculare* and "other" species were reduced ($P < 0.005$ and $P < 0.001$) when nitrogen rate increased from 40 to 160 kg/ha; *S. media* and *M. recutita* showed no response (Fig. 1). These differences in response to nitrogen application are reflected in the weight of individual plants of the species studied. All species, with the exception of *S. media*, became less frequent as nitrogen increased.

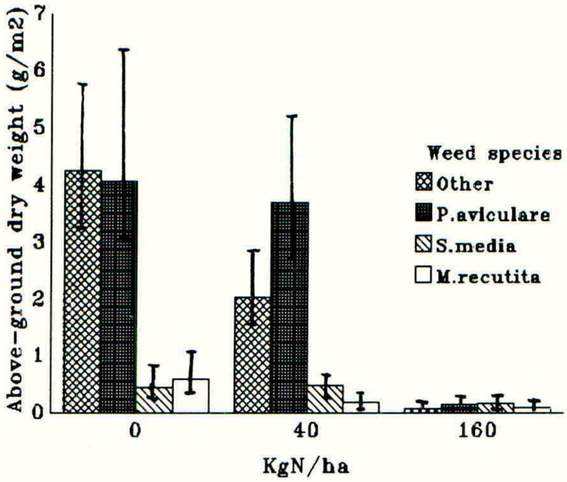

Fig 1. Above-ground dry weight for weed species at the final harvest on 27 July. Data represents mean of all seed rates and both cultivars. (Data have been back transformed following a $\log_{10}$ transformation and error bars indicate confidence limits).

TABLE 2. The effect of cultivar and crop seed rate on the total weed density and above-ground dry weight for *M. recutita* on 27 July 1992[b].

	Numbers/m^2	Above-ground dry weight (g/m^2)
Cultivar		
Maris Huntsman	2.6	-0.77(1.57)
Mercia	8.7	-0.20(4.32)
SE	1.4	0.14
P	$p<0.01$	$p<0.001$
Crop seed rate/m^2		
250	9.2	-0.15(6.66)
350	6.7	-0.46(1.99)
450	1.1	-0.84(0.19)
SE	1.8	0.18
P	$p<0.01$	$p<0.05$

[b] Above-ground dry weights have been $\log_{10}$ transformed for statistical analysis and figures in parentheses refer to untransformed data.

Choice of cultivar was observed to have a significant effect only on the total above-ground weight/m^2 and numbers for *M. recutita* and only at final harvest ($P<0.01$). A similar effect was found in the effect of crop seed rate where increased sowing density reduced *M. recutita* in terms of above-ground dry weight/m^2 ($P<0.05$) and numbers/m^2 ($P<0.01$ Table 2).

DISCUSSION

Throughout the experiment, weed density, above-ground dry weight and species number decreased with the addition of higher rates of nitrogen, suggesting that by increasing nitrogen availability, far from increasing the weed infestation, it was in most cases suppressed substantially. This was almost certainly due to enhanced competition from the crop at these higher rates of nitrogen. Such observations are supported by previous work where weed density (Mahn, 1988; Grundy *et al.*, 1991) and species number (Pysek and Leps, 1991; Grundy *et al.*, 1992) have been shown to be inversely related to increasing nitrogen application.

Reductions in weed biomass in the presence of Maris Huntsman, most notably seen in *M. recutita*, may be attributed to differences in its shading ability and leaf architecture. Differences in the competitive ability of Maris Huntsman compared to the semi-dwarf variety Virtue have already been reported in trials carried out by Moss (1985) for the suppression of *Alopecurus myosuroides* (Black-grass). As light interception has been found to be significantly correlated to crop height (Wicks *et al.*, 1986) and Maris Huntsman found to be on average 20cm taller than Mercia, the taller of the two cultivars probably conferred greater shading on the understorey weed population at a given level of nitrogen availability. Increasing nitrogen rate may accentuate these differences in height and hence shading ability between cultivars and this may explain the interaction seen in the total above-ground weed dry weights at final harvest. In addition, differences in root distribution between the two cultivars should not be ignored as possible causes of differing competitive ability.

Although weed biomass was reduced by increasing crop seed rate, the effects were less marked than with cultivar and nitrogen and may have been more significant had the spatial arrangement of the rows been manipulated to give rise to a denser and more even canopy. Andersson (1986) proposed that a moderate reduction in row spacing combined with an increase in seed rate would be likely to prove advantageous. In agreement with the present study, Samuel and Guest (1990) failed to find any detectable difference in the weed population density, but did find significant reductions in above-ground biomass with the use of increased seed rates.

The results presented here indicate that the use of higher sowing rates, in conjunction with enhanced crop competitiveness in cultivar selection procedures, may offer a successful integrated approach to weed management. It is stressed however, that nitrogen availability may manipulate the nature of the weed infestation in favour of more nitrophilous species.

ACKNOWLEDGEMENTS

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HIGHER CROP SEED RATES CAN AID WEED MANAGEMENT

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ABSTRACT

Field studies were conducted with safflower in 1990 and 1991 at Lethbridge, Alberta, and with field peas in 1991 and 1992 at Lethbridge and Vegreville, Alberta, to determine if increased seed rates improve the crop's competitive ability with weeds. Increasing the seed rate of safflower, infested with 500 *Setaria viridis* plants m^{-2}, from the recommended rate of 20 to 50 kg ha^{-1} resulted in 2- to 3-fold greater yields. Concurrently, increasing the seed rate of safflower reduced *S. viridis* seed yield up to 85%. Seed costs were an extra $15 per hectare but were more than compensated by increased yields and decreased herbicide costs. By contrast, increased sowing rates only marginally increased the competitive ability of field pea with volunteer barley. At Lethbridge, increasing the seed rate of peas (infested with barley) from 150 to 225 kg ha^{-1} increased pea yield by 19% and decreased barley yield by 10%. At Vegreville, there was little benefit in increasing the sowing rate of weedy peas above 150 kg ha^{-1}. Increasing the pea seed rate from 150 to 225 kg ha^{-1} would cost growers an extra $30 to $35 per hectare. This would be a risky investment because the benefits of these higher seed rates were inconsistent. These studies suggest that the merits of higher crop seed rates to manage weeds depends on the specific crop-weed combination of concern.

INTRODUCTION

New cultivars and improved production practices have allowed field pea and safflower to become viable alternative crops to cereals on the Canadian prairies. However, inadequate weed control continues to reduce yields. Weeds compete vigorously with these crops; yield reductions up to 70% have been documented in both these crops in western Canada (Blackshaw *et al.*, 1990; Wall *et al.*, 1991).

Cultural weed control practices are an important component of integrated weed management systems and are especially useful in crops where weed control options are limited. One practice that growers can readily alter is crop seed rate. Studies with other crops have found that increased seed rates can hasten formation of dense canopies and, thus, increase the crop's ability to compete for incoming photosynthetic radiation (Berkowitz, 1988; Walker & Buchanan, 1982), shade weeds and help prevent the establishment of late weed flushes. Additionally, dense crop stands compete vigorously with weeds for soil nutrients and water.

Studies were initiated to determine the yield response of safflower and field pea to increased seed rates under weed-free and weed-infested conditions. Additionally, the effect of these higher crop seed rates on weed seed yield was determined.

MATERIALS AND METHODS

Safflower

Field experiments were conducted in 1990 and 1991 at Lethbridge, Alberta. The sandy clay loam soil had a pH of 8.0 and 2.0% organic matter. Prior to sowing in the spring, fertilizer was broadcast and incorporated to a depth of 6 cm. Phosphorus was applied at 40 kg ha^{-1} each year and nitrogen was applied to bring the total soil N to 100 kg ha^{-1}.

Saffire safflower was sown 3 cm deep in early May each year with a double-disc press drill on land that had been fallowed the previous year. Safflower was planted at 5, 20, 35, 50, 65, and 80 kg ha^{-1} and was grown weed-free or weed-infested. Treatments were arranged in a randomized complete block design with four replications. Individual plot size was 2.5 m wide and 8 m long.

Safflower emergence ranged from 70 to 85% in these tests. Plant counts shortly after emergence determined that the resultant mean safflower densities were 10, 40, 70, 100, 130 and 160 plants m^{-2} in 1990, and 12, 48, 84, 120, 156 and 192 plants m^{-2} in 1991. The indicator weed species *Setaria viridis* (green foxtail) was sown perpendicular to the safflower rows at 8 kg ha^{-1} in 11 cm rows in the weedy plots. This resulted in mean *S. viridis* densities of 480 and 535 plants m^{-2} in 1990 and 1991 respectively. Other weed species were removed by hand-weeding throughout the growing season.

Seed yield of safflower and *S. viridis* at maturity was determined by harvesting 5 m^2 from the centre portion of each plot with a small plot combine. Harvested samples were subsequently cleaned to separate safflower and *S. viridis* seed.

All data were subjected to analysis of variance. Analyses of variance over years indicated a significant ($P<0.05$) year by treatment interaction for all data. Thus, data were analyzed and presented separately for each year. Safflower and *S. viridis* seed yield data were subjected to regression analysis.

Field Pea

Field experiments were conducted in 1991 and 1992 at Lethbridge and Vegreville, Alberta. At Lethbridge, the soil type was similar to that reported for the safflower study. At Vegreville, the soil was a sandy loam with a pH of 6.7 and 6% organic matter. Prior to sowing in the spring, fertilizer was broadcast and incorporated to a depth of 6 cm. Phosphorus was applied at 40 kg ha^{-1} each year and nitrogen was applied to bring the total soil N to 100 kg ha^{-1}.

Semi-leafless Radley peas were sown 5 cm deep in early May each year with a double-disc press drill on land that had been fallowed the previous year. Peas were sown at 75, 150, 225, 300 and 375 kg ha^{-1}, and were grown weed-free or weed-infested. Resultant pea densities were 50, 100, 150, 200 and 250 plants m^{-2}. The indicator weed species, spring barley (cv. Galt) (a common volunteer crop in peas in western Canada), was planted perpendicular to the pea rows in 11 cm rows at densities of 0, 5, 20, 60 and 120 plants m^{-2}. Peas and barley were counted and thinned to the desired stands shortly after emergence. Other weed species were removed by hand-weeding. Treatments were replicated four times and individual plot size was 2.5 by 2.5 m.

Seed yield of peas and barley at maturity was determined by hand harvesting respective species from a 1 m^2 area in the centre portion of each plot. Analyses of variance indicated significant location ($P<0.05$) but not year effects, thus data were pooled over years for each location for presentation.

RESULTS

Safflower

Safflower seed yield increased with increasing plant density until some upper limit was attained. This response occurred for both weed-free and weedy safflower but the density at which optimum yield occurred differed depending on the presence or absence of *S. viridis*. Weed-free safflower yield did not significantly increase above a density of 70 plants m^{-2} in 1990 and 84 plants m^{-2} in 1991 (Figure 1). However, safflower infested with *S. viridis* increased in yield up to 100 plants m^{-2} in 1990 and 156 plants m^{-2} in 1991. Increasing the density of safflower could not completely negate the suppressive effects of *S. viridis* but weedy safflower yields were three to four times greater at high than at low plant densities.

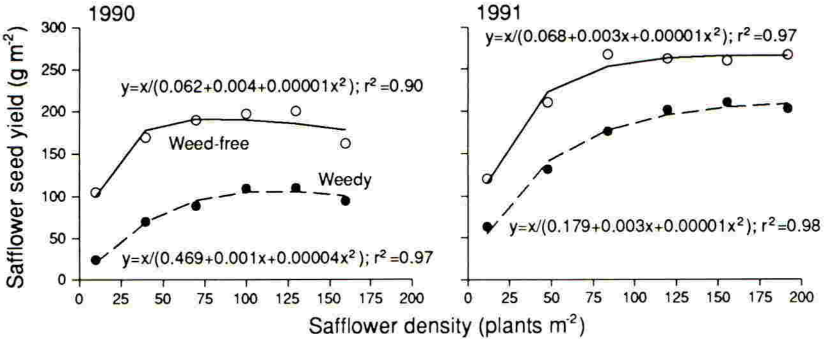

Figure 1. Safflower seed yield response to increasing plant density when grown weed-free or infested with *Setaria viridis*.

S. viridis seed yield decreased with increasing safflower densities in both years (Figure 2). Compared to seed yields when grown alone, *S. viridis* yield was reduced 74% in 1990 and 85% in 1991 at the highest density of safflower.

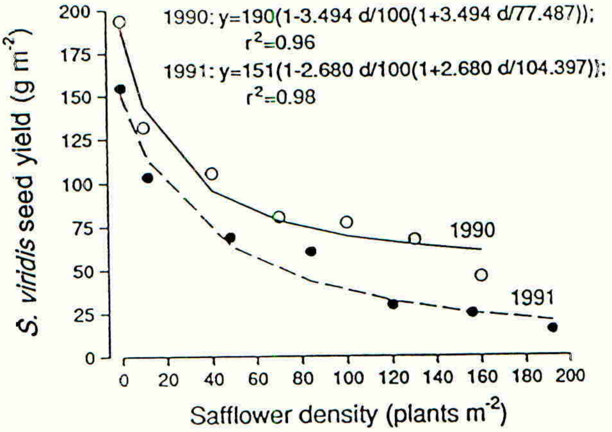

Figure 2. *Setaria viridis* seed yield response to increasing safflower densities.

Field Pea

Weed-free pea seed yield increased as pea density was increased from 50 to 100 plants m^{-2} at both Lethbridge and Vegreville (Figure 3). However, no further significant increases in pea yield occurred at either location as pea density increased from 100 plants m^{-2} (150 kg ha^{-1}) to 250 plants m^{-2} (375 kg ha^{-1}).

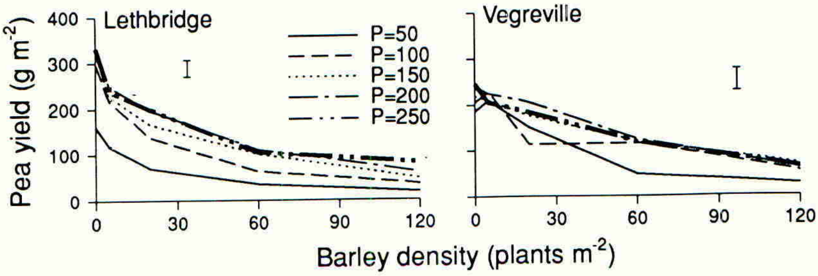

Figure 3. Field pea seed yield response at various plant densities grown weed-free or infested with vairous densities of barley. P represenets pea density in plants m^{-2}. Bars represent standard error of the mean.

Barley competed vigorously with peas. Averaged over both locations and at the recommended pea density of 100 plants m^{-2}, pea yields were reduced 30 and 85% by barley densities of 10 and 120 plants m^{-2}, respectively (Figure 3). At Lethbridge, peas infested with barley increased in yield as pea density was increased up to 150 plants m^{-2} (225 kg ha^{-1}). Averaged over the range of barley densities, peas yielded 19% more at 150 than at 100 plants m^{-2}. Further increases in pea density above 150 plants m^{-2} did not significantly increase pea yield. At Vegreville, peas infested with barley only increased in yield as pea density was increased up to 100 plants m^{-2}.

Barley grown with peas increased in yield as its density was increased from 5 to 120 plants m^{-2} at Lethbridge and Vegreville (Figure 4). Increasing the density of peas decreased barley yields slightly at both locations. At Lethbridge, averaged over all barley densities, increasing the pea density from 100 to 150 and 200 plants m^{-2} decreased barley yields by 10 and 24%, respectively. In contrast, at Vegreville, increasing the pea density above 100 plants m^{-2} did not significantly decrease barley yield.

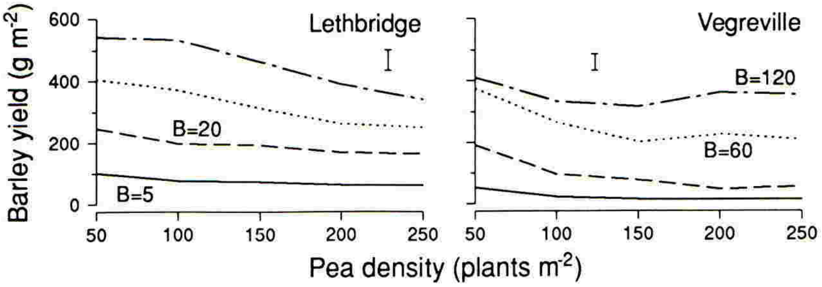

Figure 4. Barley seed yield response at various plant densities grown with various densities of field pea. B represents barley density in plants m^{-2}. Bars represent standard error of the mean.

DISCUSSION

Recommended safflower seed rates of 20 to 30 kg ha^{-1} on the Canadian prairies usually results in stands of 50 to 70 plants m^{-2}. Under weed-free conditions greater safflower densities may give small yield increases depending on the growing conditions, but under weedy conditions yield increases are likely to be consistent and much larger; up to 3- or 4-fold in this study with *S. viridis*. Increasing safflower seed rate from 20 to 50 kg ha^{-1} would cost growers an extra \$12 to \$15 per hectare. This cost is not prohibitive and would be more than compensated for by increased yields and decreased herbicide costs.

Increasing the seed rate of weed-free peas above the recommended 150 kg ha^{-1} did not result in greater pea yields at either location. At Lethbridge, increasing the seed rate of weedy peas from 150 to 225 kg ha^{-1} increased pea yield by 19% and decreased barley yield by 10%. At Vegreville, there was little benefit from increasing the seeding rate of weedy peas above 150 kg ha^{-1}. Increasing the pea seed rate from 150 to 225 kg ha^{-1} would cost growers an extra \$30 to \$35 per hectare. This would be a risky investment because the benefits of these higher seed rates were inconsistent in this study. Results with peas may be different with a less competitive weed species than barley; thus, additional studies are warranted.

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EFFECT OF RECOMMENDED AND REDUCED RATE HERBICIDES ON WEED NUMBER, YIELD AND GROSS MARGIN IN TALISMAN : REPORT ON THE FIRST TWO YEARS

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ABSTRACT

TALISMAN (Towards A Lower Input System Minimising Agrochemicals and Nitrogen) was started in autumn 1990 at four ADAS Research Centres on soils ranging from clay to sandy loam. Standard and alternative six-year rotations are being tested under a Current Commercial Practice (CCP), applying full recommended rates and Low Input Approach (LIA) in which 50% of the nitrogen and a maximum of 50% of the pesticide amounts are used. The design allows the effect of reducing the rate of herbicides to be assessed separately from other pesticides. During the first two years the crops grown included most major arable crops in rotations appropriate to the soil type of the centre concerned. In each year, there were comparisons between CCP and LIA, giving 25 situations over the two years. In 12 cases, yield of LIA for herbicides has been less than CCP, only four of which were very large. In only seven cases did LIA result in lower margins. The largest reductions in margin were associated with oilseed rape, especially from inadequate control of volunteer wheat. The long-term effects of reduced herbicide inputs in the various rotations are being evaluated.

INTRODUCTION

A major, multi-disciplinary project to investigate the environmental and economic effects of pesticide use in intensive cereal production was done at ADAS Boxworth Research Centre in 1981 - 1988; this study became known as the Boxworth Project (Greig-Smith *et al.*, 1992). It showed that lower input systems of crop production were not always less economically viable and that many beneficial invertebrates were adversely affected by high input regimes, often associated with specific pesticide applications. To study these effects further, two experiments were started at a larger number of sites. TALISMAN (Towards A Lower Input System Minimising Agrochemicals and Nitrogen) was designed to measure the economic, agronomic and, to a lesser extent, the environmental effects of adopting cropping systems which use lower levels of agrochemicals and nitrogen than conventional cropping systems. A sister experiment, called SCARAB, aims to examine the environmental effects in more detail (Bowerman, 1993).

MATERIALS AND METHODS

TALISMAN is located at four ADAS Research Centres of varying soil type (Table 1). However, the Gleadthorpe site was terminated in the second year due to unpredictable variation in soil. Standard and alternative six course rotations are being tested under a Current Commercial Practice (CCP) approach for pesticides and nitrogen and a Lower Input Approach (LIA) in which 50% of the nitrogen rate applied to CCP and a maximum of 50% of the pesticide rates are used. The standard rotations are typical for the individual sites and the alternative rotations are based predominantly on spring crops which have an inherently lower requirement for pesticides and nitrogen (Table 1). The experiment started before the introduction of set-aside and the rotations will not be changed; effects of set-aside are being studied in other experiments.

Pesticides in CCP are applied at the manufacturers' label recommended rates. It is recognised that in appropriate circumstances many farmers apply pesticides at less than the recommended rate. However, the full rate is robust and gives the best control in most situations and provides a recognised standard against which comparisons can be made. Nitrogen rates are determined using "Fertiplan", which is an ADAS fertiliser planning service based on previous cropping, soil type and yield prediction. Wherever possible, the reduction in LIA pesticides is being achieved by omitting applications altogether. However, if it is estimated that the loss of crop value would be greater than 10% by withholding the agrochemical, then up to half of the rate applied to CCP can be used. A full rate application is allowed in very exceptional instances when there is already conclusive evidence that less than the full rate would result in a crisis. The agrochemical products, cultivars, cultivation and sowing date are the same in both CCP and LIA.

The experiment is designed to compare the individual performance of herbicides, fungicides and insecticides at CCP and LIA rates at normal and half rates of nitrogen. TALISMAN has a split-plot design with rotation and nitrogen rate as main treatments and combinations of the CCP and LIA rates of herbicides, fungicides and insecticides are represented in sub-treatments. This paper only reports on the effects of LIA herbicides. All other inputs, including nitrogen are at the full CCP rate.

TABLE 1. Soil type, crop in the year before the experiment and rotations at sites of TALISMAN experiment.

Year	Boxworth	Drayton	Gleadthorpe	High Mowthorpe
Soil type	Well structured clay	Heavy clay	Sandy loam	Silty clay loam
Previous crop	W. Wheat	W. Wheat	S. Barley	W. Wheat
Standard rotations				
1	W. Oilseed rape	W. Oilseed rape	Sugar beet	W. Oilseed rape
2	W. Wheat	W. Wheat	S. Wheat	W.Wheat
3	W. Wheat	W. Wheat	W. Barley	W. Wheat
4	W. Beans	W. Beans	Potatoes	W. Beans
5	W. Wheat	W. Wheat	W. Wheat	W. Wheat
6	W. Wheat	W. Wheat	W. Barley	W. Barley
Alternative rotations				
1	Linseed	S. Beans	S. Beans	S. Beans
2	W. Wheat	Triticale	S. Wheat	W. Wheat
3	S. Wheat	Triticale	S. Barley	S. Barley
4	S. Beans	S. Oats	Peas	Linseed
5	W. Wheat	Triticale	S. Wheat	W. Wheat
6	S. Wheat	Triticale	S. Barley	S. Barley

Main plots are 24m x 24m and divided into 5 equal sub-plots. There are four replicates at Boxworth and three at Drayton, Gleadthorpe and High Mowthorpe. To take some account of the effects of seasonality, there are two phases of the experiment, achieved by commencing plots in the rotation at years 1 and 4 in 1990/91, e.g., in the standard rotation at Boxworth there were crops of winter beans and winter oilseed rape in that year. Yields are measured using plot combines. Plant counts are made throughout the season in quadrats of at least $0.1m^2$. Results quoted in Table 2 are those recorded after the full effects of the final herbicide application was evident. The key weed species reported in the table represent species most likely to have caused significant loss in yield or quality. The levels of weed seeds in the soil are being monitored by the Scottish Crop Research Institute. The economic margins have been calculated from prices achieved for the produce less average input costs.

RESULTS AND DISCUSSION

Although the principal aim is not to look at individual products some trends have emerged from the first two years of the six-year study. The effects on gross margins of reducing herbicide inputs usually followed the same pattern as the effects on yield (Table 2). Of the 25 comparisons over the two years, LIA by comparison with CCP has given actual yield losses on 12 occasions but in only four of these was this greater than 5%. In even fewer cases were the differences statistically significant. The gross margin has been reduced in only seven and many of these are very small. In several cases, there were small yield increases from the LIA rates of herbicide. This could be a result of less phytotoxic effect by using lower rates of herbicide.

The severest yield and margin reductions occurred in oilseeed rape at Boxworth in 1990/91 (£110/ha penalty). In particular, this was a result of poor control of volunteer wheat from reduced doses of grass weed herbicides. This was the result of a poorly established oilseed rape crop coupled with insufficient control from the reduced rate of fluazifop-P-butyl. The importance of controlling volunteer cereals has been demonstrated before by Ogilvy (1989).

By comparison, the reduction in herbicide use in winter and spring beans resulted in increases in margin (range £3-117/ha). Similar results demonstrating the opportunity to reduce herbicide inputs into beans have been reported by Heath *et al*. (1991) and Cook *et al*. (1991). Heath *et al*. (1991) referred to the long term consequences of lower levels of weed control requiring consideration. TALISMAN has demonstrated clearly these risks. At Drayton, wild-oats (*Avena fatua*) built up in the open canopy of spring beans, but did not do so in the spring oats. The effect of the carryover into the subsequent triticale was clearly demonstrated. Much higher levels of wild-oats were present after spring beans ($5.3/m^2$) than after spring oats ($2.0/m^2$) when assessed on low input herbicide plots on 20 May 1992.

In all except two of the comparisons, reduced herbicide use in cereal crops resulted in positive increases in margin. Previous work (Proven *et al*., 1991) in continuous cereals has shown the benefit of reducing herbicide inputs on margins. It should be noted, however, that in TALISMAN the herbicides used for black-grass (*Alopecurus myosuroides*) are not reduced in rate since it has clearly been demonstrated in previous work that reductions in the rate of herbicide used gave insufficient control (Clarke, 1987). It is interesting, that in both the wheat crops following linseed reduced herbicide inputs resulted in £24-36/ha lower margins. The reason for this is not clear since at Boxworth the wheat appeared free from weeds. However, at High Mowthorpe the low input treatment resulted in high levels of cleavers (*Galium aparine*).

In the small number of comparisons for linseed and sugar beet, yield was always reduced from the use of LIA rates of herbicide, although the financial penalty was not always very large. An interesting lesson was learned at Boxworth where it was intended to establish the linseed after use of glyphosate

TABLE 2. Cropping position, herbicide treatment and divergence of total weed number/m², seed, ware or root yield and margin over herbicide costs of LIA from CCP in harvest years 1991 and 1992.

Crop	Herbicide treatment	Rate (g AI/ha)		Divergence of LIA (herbicide) from CCP			
		CCP	LIA	Total weeds	Key species	Yield (t/ha)	Margin (£/ha)
Boxworth 1990/91							
W. Beans	simazine +	1150	nil	+23.0	cleavers, wheat, black-grass	+0.20	+66
	propyzamide	425	nil				
W. Oilseed rape	fluazifop-P-butyl	125	62.5	+22.5	wheat	-0.47	-110
Linseed	glyphosate	540	nil	NA	NA	-0.12	-24
	cycloxydim	nil	150				
1991/92							
W. Wheat after W. Beans	diflufenican +	100	50	+3.0	cleavers	-0.08	+5
	isoproturon	2500	2500				
	mecoprop-P +	900	450				
	bromoxynil +	300	150				
	ioxynil	300	150				
	fenoxaprop-ethyl	180	180				
W. Wheat after Oilseed rape	diflufenican +	100	50	0	nil	+0.02	+15
	isoproturon	2500	2500				
	fluroxypyr	200	100				
	fenoxaprop-ethyl	180	180				
W. Wheat after Linseed	diflufenican +	100	50	0	nil	-0.26	-24
	isoproturon	2500	2500				
	fenoxaprop-ethyl	180	180				
Drayton 1990/91							
W. Oilseed rape	fluazifop-P-butyl	125	125	-11.0	field speedwell, fool's parsley	-0.38	-69
	sethoxydim	338	nil				
W. Beans	simazine	1100	1100	+0.7	wild-oats	+0.47	+117
	sethoxydim	338	nil				
S. Beans	simazine +	173	nil	+2.0	wild-oats, fool's parsley	-0.12	+7
	trietazine	1208	nil				
S. Oats	bromoxynil +	240	120	+2.7	nil	+0.16	+28
	ioxynil +	160	80				
	mecoprop-P	1380	690				
1991/92							
W. Wheat after Oilseed rape	diflufenican +	100	50	+2.8	cleavers	+0.61	+104
	isoproturon	1000	500				
	fenoxaprop-ethyl	150	75				
	bromoxynil	252	126				
	ioxynil	252	126				
	mecoprop	2016	1008				
W. Wheat after W. Beans	diflufenican +	100	50	+11.2	nil	+0.39	+75
	isoproturon +	1000	500				
	mecoprop-P	600	300				
	fenoxaprop-ethyl	150	75				
	bromoxynil +	252	126				
	ioxynil +	252	126				
	mecoprop	2016	1008				

TABLE 2. (continued)

Crop	Herbicide treatment	Rate (g AI/ha)		Divergence of LIA (herbicide) from CCP			
		CCP	LIA	Total weeds	Key species	Yield (t/ha)	Margin (£/ha)
Triticale	chlorotoluron	3500	1750	+15.3	wild-oats,	+0.17	+62
after S. Beans	difenzoquat	975	488		field speedwell		
	bromoxynil +	252	126				
	ioxynil +	252	126				
	mecoprop	2016	1008				
Triticale	chlorotoluron	3500	1750	+4.8	wild-oats	+0.01	+45
after S. Oats	difenzoquat	975	488				
	bromoxynil +	252	126				
	ioxynil +	252	126				
	mecoprop	2016	1008				
Gleadthorpe 1990/91							
Sugar Beet	chloridazon +	963	481	+5.4	nil	-3.07	-7
	ethofumesate	595	298				
	metamitron +	875 x 2	438 x 2				
	phenmedipham	194 x 2	97 x 2				
	ethofumesate +	300	150				
	phenmedipham +	240	120				
	clopyralid	200	100				
Potatoes	linuron +	1680	840	+0.7	nil	+4.98	+382
	paraquat	200	100				
S. Beans	simazine +	104	nil	+45.4	nil	-0.03	+3
	trietazine	725	nil				
	trietazine +	nil	250				
	terbutryn	nil	250				
High Mowthorpe 1990/91							
W. Oilseed rape	propyzamide	875	440	+82	chickweed, poppy,	-0.15	-11
					speedwell, wheat		
W. Beans	nil	nil	nil	+2	cleavers, poppy	+0.30	+55
S. Beans	nil	nil	nil	+8.4	poppy	+0.19	+36
Linseed	bentazone +	960	480	+8.0	poppy,	-0.13	+14
	clopyralid	50	25		black bindweed		
1991/92							
W. Wheat	diflufenican +	100	50	+5.5	cleavers,	+0.05	+17
after OS rape	isoproturon	1000	500		potatoes		
W. Wheat	diflufenican +	100	50	+8	poppy,	+0.08	+25
after W. Beans	isoproturon	1000	500		potatoes		
	mecoprop-P	1200	600				
W. Wheat	diflufenican +	100	50	+20.5	cleavers	-0.31	-36
after Linseed	isoproturon	1000	500				
W. Wheat	diflufenican +	100	50	+9.8	cleavers,	-0.02	+8
after S. Beans	isoproturon	1000	500		potatoes		

Weed species: black-grass (*Alopecurus myosuroides*), chickweed (*Stellaria media*), cleavers (*Galium aparine*), field speedwell (*Veronica persica*), fool's parsley (*Aethusa cynapium*), poppy (*Papava rhoeas*), wild-oats (*Avena fatua*).

pre-cultivation on the CCP plots. On the LIA plots it was intended to use a lower rate closely followed by cultivation, hopefully giving satisfactory contol of brome and black-grass, thus reducing pesticide inputs. In practice, due to the weather, it was not possible to apply this delayed application and to safeguard the crop cycloxydim was required on the LIA plots, thus incurring a greater cost. The single comparison in potatoes resulted in higher, but not significant, yield and margin from reduced rate herbicide. Weed number was similar. Damage to emerging potato haulm from the linuron + paraquat herbicide, applied at early post-emergence, was less severe on the LIA herbicide plots.

Results for reductions of inputs across the range of pesticides tested suggest that significant savings may result from reducing rates of many pesticides (Bowerman, 1993). Similar to the situation with herbicides, this is most easy with cereals but more difficult for broad-leaved break crops. Attention to applying the appropriate rate has been highlighted as crucial. There is large scope for reductions in herbicide inputs. Identifying where reduction will cause penalties is most important. TALISMAN is indicating that there are potential savings to be made with herbicide inputs, particularly with cereals, but large penalties can be incurred from omitting or reducing key inputs or ignoring the longer term and rotational consequences. For instance, the poor control of volunteer cereals in break crops can lead to carry over of take-all (*Gaeumannomyces graminis*) inoculum which may lead to lower yields. Provisional evidence from the Boxworth site, just prior to harvest 1993, suggests that there may be differing levels of take-all in the wheat as a result of poor control in 1991. Similarly, volunteers will lead to contamination of subsequent crops with resultant losses in quality. The skill required to get the correct balance of inputs is likely to become greater as the pressure to reduce inputs increases.

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EFFICACY OF DIMETHENAMID, METOLACHLOR AND ENCAPSULATED ALACHLOR IN SOIL COVERED WITH CROP RESIDUE

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ABSTRACT

The practice of conservation tillage where the crop residue is left on the surface of the soil has gained acceptance in recent years. For effective pre-emergence weed control in conservation tillage agricultural systems, herbicides must pass through the crop residue and reach the weed seed germination zone in the soil. Dimethenamid (Frontier) is a new thiophenamine herbicide that has been developed for pre-emergence control of grass and small-seeded broad-leaved weeds in corn and soybean. The efficacy of this new herbicide was compared with metolachlor (Dual) and encapsulated alachlor (Microtech) by evaluating *Setaria viridis* control following herbicide application to bare soil or soil covered with soybean, corn or oat residue at 1.12 to 8.96t/ha. The herbicides were washed off the surface of the crop residue by applying 1.6 to 12.8mm simulated rainfall. Under the heavy crop residue and low rainfall conditions of these experiments, dimethenamid consistently provided greater weed control than metolachlor and encapsulated alachlor. The type of crop residue present on the soil surface did influence weed control. Herbicide efficacy was least affected in the presence of soybean residue; whereas, it was most affected in the presence of oat residue.

INTRODUCTION

There is increasing emphasis on conservation tillage in many areas of the world (Watson and Allen, 1985). Conservation tillage is gradually replacing conventional tillage. During the period from 1972 to 1992 the total no-till and minimum-till conservation tillage acreages increased by 674% and 236%, respectively, in such crops as corn, soybean, small grains, sorghum, forages and cotton (Lessiter, 1992).

There are several advantages to using conservation tillage. Runoff and erosion of soil can be reduced if crop residues remain on the soil surface. By controlling runoff and erosion, highly erodible land and land not previously used to grow crops can be brought into production (Harman and Wiese, 1985). In addition, land preparation for conservation tillage requires less fuel and labour, and less wear occurs on machinery (Gebhardt and Farnstrom, 1985). Furthermore, since conservation tillage minimizes runoff and evaporation of moisture from the soil surface, the amount of soil water available to plants is increased. One of the major limitations of using conservation tillage is weed proliferation in the absence of adequate cultivation. In conservation tillage, therefore, the use of chemicals to control weeds takes on an important role (Barrows *et al.*, 1952; Davidson and Barrows, 1954).

Crop residue on the surface of conservation tillage fields can intercept a portion of the applied herbicide and prevent it from reaching the weed seed germination zone. Several workers have reported inconsistent efficacy of atrazine when applied to reduced tillage fields (Kells *et al.*, 1980; Robinson and Wittmuss, 1973; Triplett and Lyle, 1972). This was attributed to, among other factors, rainfall needed to wash the herbicide from plant residue. In a conservation tillage system, Strek and Weber (1981) reported better grass weed control with metolachlor than with alachlor in a dry year and equal control from both herbicides in a wet year. The higher water solubility of metolachlor (530mg/l) compared to alachlor (242mg/l) may have increased the amount of metolachlor washed off of the crop residue and into the soil when rainfall was limited. Dimethenamid, a new herbicide for pre-emergence control of grass and small-seeded broad-leaved weeds in corn and soybean, is somewhat more water soluble (1174mg/l) than metolachlor or alachlor and thus should more readily wash off of crop residue and provide better weed control under low rainfall conditions.

The purpose of this research was to compare the efficacy of dimethenamid, metolachlor, and encapsulated alachlor, which has largely replaced conventionally formulated alachlor in the U.S., under simulated conservation tillage conditions.

MATERIALS AND METHODS

General procedure

Crop residues were collected from fields which received no pesticides during the preceding growing season. Residues were dried in a glasshouse for at least two weeks prior to use.

Containers made of plastic (23cm x 15cm x 5cm) were filled with a sandy loam soil (65% sand, 19% silt, 16% clay, and 0.7% o.m.). The cation exchange capacity was 16meq/100g and the pH was 7.4. Crop residue was placed on the soil surface in amounts ranging from 1.12t/ha to 8.96t/ha.

Herbicides and simulated rainfall were applied using a linear track sprayer calibrated to deliver 327l/ha to the soil surface or to the crop residue covering the soil surface. There was a two hour interval between herbicide and rainfall application. Crop residue was placed on the surface of the no residue (bare soil surface) treatments just prior to rainfall application to compensate for differences in the amounts of moisture reaching the soil surface. The crop residue was removed from all treatments two hours after rainfall application to ensure good germination and subsequent growth of the bioassay species, *Setaria viridis* (green foxtail). Additional moisture was applied via sub-irrigation.

Rates of all herbicides were reduced for glasshouse application. The rates were then adjusted to reflect relative differences in manufacturers' recommended field use rates. Dimethenamid (900g/litre) rates ranged from 224 to 560g AI/ha. Rates of metolachlor (960g/litre) ranged from 376 to 940g AI/ha, and those of encapsulated alachlor (480g/litre) ranged from 0.448 to 1.12kg AI/ha.

Influence of rainfall

To determine the influence of rainfall amounts on herbicide efficacy, corn residue at 4.48t/ha was placed on the soil surface. Dimethenamid, metolachlor, and encapsulated alachlor were applied at 224g AI/ha, 376g AI/ha, and 448g AI/ha, respectively. Rainfall was applied in amounts ranging from 0 to 12.8mm. *S. viridis* control was evaluated 21 DAT.

Influence of amount of crop residue

The effect of the amount of crop residue on herbicide efficacy was investigated in a separate experiment. Corn residue was placed on the soil surface in amounts ranging from 0 to 8.96t/ha. Herbicide application rates were the same as those in the previous experiment. The amount of rainfall applied was 3.2mm, and weed control was evaluated 21 DAT.

Influence of crop residue type

The effect of corn, soybean, and oat residues was determined using herbicide rates of 0.56kg AI/ha, 0.94kg AI/ha, and 1.12kg AI/ha for dimethenamid, metolachlor, and encapsulated alachlor, respectively. Higher rates than in previous experiments were used to ensure adequate *S. viridis* control in the presence of different crop residues. In this experiment, all treatments received only 3.2mm of rainfall following herbicide application. *S. viridis* control was evaluated 21 DAT.

RESULTS

Influence of rainfall

All three herbicides, dimethenamid, metolachlor and encapsulated alachlor, provided 62 to 71% control of *S. viridis* in the absence of rainfall following application of the herbicides to bare soil (Table 1). With no crop residue, application of simulated rainfall significantly improved weed control from dimethenamid and metolachlor, but not from encapsulated alachlor.

TABLE 1. Influence of rainfall on *S. viridis* control with dimethenamid, metolachlor, and encapsulated alachlor applied to bare soil or to soil covered with corn residue.

Herbicide	Rate	Corn residue	Rainfall (mm) 0	1.6	3.2	6.4	12.8
	(g/ha)	(t/ha)	% control				
Dimethenamid	224	0	62	73	83	87	82
Dimethenamid	224	4.48	33	40	59	75	84
Metolachlor	376	0	71	77	79	87	85
Metolachlor	376	4.48	41	44	65	76	74
Encapsulated Alachlor	448	0	64	68	72	68	64
Encapsulated Alachlor	448	4.48	23	29	35	36	39

LSD (0.05) = 11

The presence of corn residue on the surface of the soil significantly reduced the efficacy of all three herbicides in the absence of rainfall. However, when a minimum of 3.2mm rainfall was applied, weed control from all three herbicides improved significantly, and with 12.8mm rainfall the efficacy of dimethenamid became equal to that obtained without crop residue. The efficacy of metolachlor and encapsulated alachlor did not reach the level equivalent to no crop residue.

Influence of amount of crop residue

In the absence of any corn residue, all three herbicides provided 93 to 97% control of *S. viridis* after 3.2mm of rainfall (Fig. 1). As the amount of corn residue increased from 0 to 8.96t/ha, the efficacy of dimethenamid and metolachlor was reduced by about 20% and 30%, respectively. Efficacy of encapsulated alachlor was reduced by more than 80% in the presence of 8.96t/ha of corn residue.

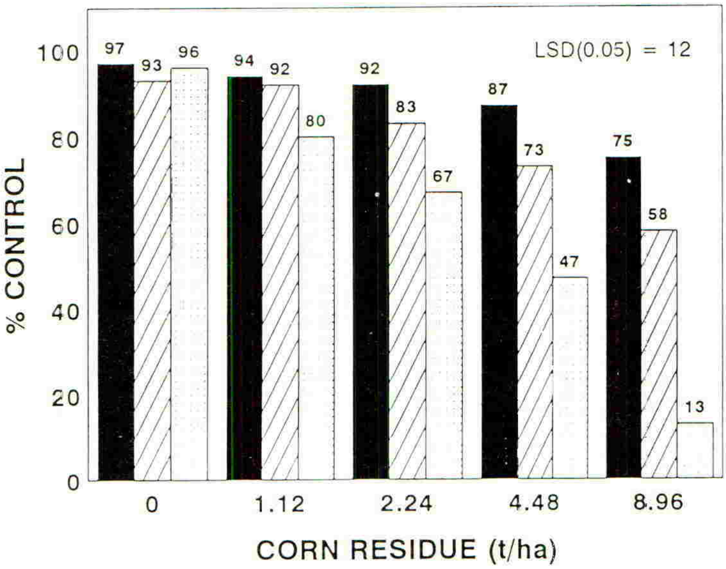

Fig. 1. Effect of the amount of corn residue on *S. viridis* control by ■ dimethenamid (224g/ha), ▨ metolachlor (376g/ha), and ☐ encapsulated alachlor (448g/ha). Amount of rainfall applied was 3.2mm.

Influence of residue type

In general, the efficacy of dimethenamid was affected least by the presence of corn, soybean and oat residues and that of encapsulated alachlor was affected most. The results with corn residue (Fig. 2A) were similar to those of earlier experiments evaluating the influence of rainfall (Table 1) and the amount of crop residue (Fig. 1). Oat residue (Fig. 2B) had the greatest effect on the efficacy of the herbicides, reducing the efficacy of dimethenamid, metolachlor and encapsulated alachlor by 19%, 32% and 54%, respectively. Soybean residue did not have a significant effect on the efficacy of

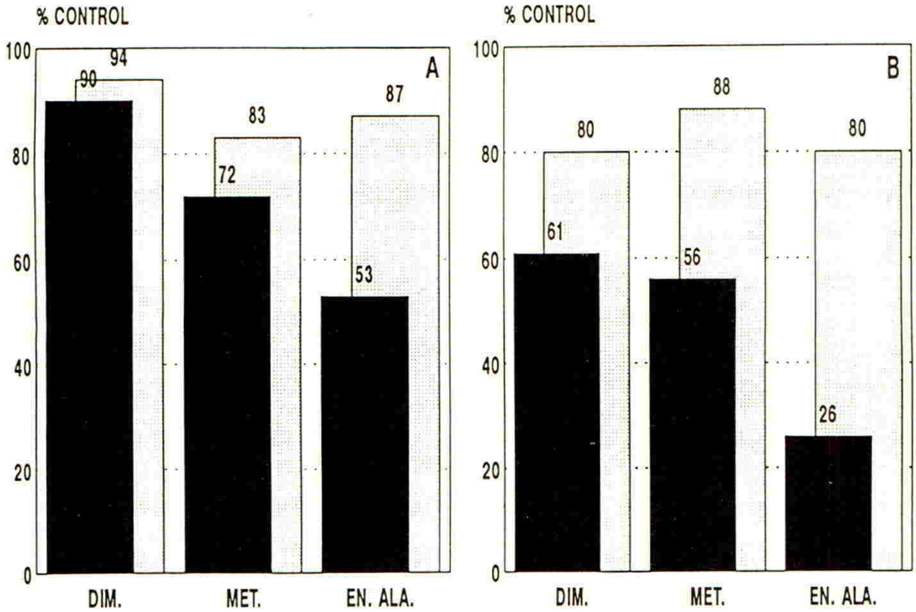

Fig. 2. Efficacy of dimethenamid (0.56kg/ha), metolachlor (0.94kg/ha), and encapsulated alachlor (1.12kg/ha) for *S. viridis* control in ▢ soil not covered with residue and in ■ soil covered with 4.48t/ha (A) corn residue [LSD(0.05) = 12] and (B) oat residue [LSD(0.05) = 10]. Amount of rainfall applied was 3.2mm.

dimethenamid and only slightly reduced (8-10%) the efficacy of metolachlor and encapsulated alachlor (data not shown).

DISCUSSION

Pre-emergence herbicides require some amount of rainfall to be effective even when applied to bare soil. Rainfall helps in the movement of the herbicides into the weed seed germination zone. At the relatively low rainfall amounts used in this investigation, the phenomenon of rainfall activation was observed with dimethenamid and metolachlor, but not with encapsulated alachlor, which perhaps requires a higher level of rainfall to aid in the release of the herbicide from surface crop residue or the polyurea capsules. Even without an effect due to encapsulation, Strek and Weber (1981) reported better grass weed control with metolachlor than with alachlor in reduced tillage. Differences were attributed to the higher water solubility of metolachlor.

Crop residue present on the surface of the soil can intercept a portion of the herbicide spray and thus reduce the efficacy of herbicides. The amount of herbicide spray intercepted depends on the soil surface area covered by the crop residue. In the experiments reported here, the soil surface area covered by 1.12 to 8.96t/ha of corn residue was estimated to be from 20 to 95%, respectively. Therefore, some herbicide spray was able to reach the soil surface in the absence of rainfall. The efficacy of all three herbicides decreased, however, in proportion to the amount of corn residue present on the soil surface. As rainfall was applied, a greater proportion of dimethenamid was washed off the crop residue and reached the soil surface. The primary reason proposed is the somewhat higher water solubility of dimethenamid when compared to metolachlor and alachlor. Lowder and Weber (1979) reported that the amount of rainfall required to remove atrazine from plant residue was primarily dependent upon the total amount of rainfall received and secondarily dependent upon residue type and rainfall pattern. In their experiments, 10cm of water were required to wash off 80% of the applied atrazine.

The three types of crop residues differed in their capacity to cover the soil surface and to retain the herbicides. Soybean residue at a rate of 4.48t/ha provided essentially 100% soil cover, but did not greatly affect the efficacy of the three herbicides. The same amount of corn residue; however, provided only 60 to 70% soil cover, yet significantly reduced the efficacy of all three herbicides. This observation suggests that residue morphology and absorption/adsorption characteristics affect herbicide retention. Further research is needed to characterize the herbicide binding properties of the various types of crop residues.

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