SESSION 4A

ENVIRONMENTAL IMPACT – MANAGEMENT AND MANIPULATION OF VEGETATION INCLUDING BRACKEN

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ENVIRONMENTAL IMPACT OF CHEMICAL WEED CONTROL IN ARABLE FIELDS IN THE FEDERAL REPUBLIC OF GERMANY

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ABSTRACT

In the Federal Republic of Germany, the protection of the environment is ruled by the "polluter pays" principle, the principle of prevention of damage, and the principle of co-operation. The intensification of agriculture has resulted in a decline in the diversity of weed floras. Chemical weed control is considered to be the major contributory factor. Weed species communities are being conserved on unsprayed and less fertilised field margins thus linking agriculture and nature conservation. The weed-feeding fauna is mainly influenced via indirect effects on food chains. Side-effects of herbicides on soil micro-organisms have to be assessed according to inhibition or stimulation of microbial activities.

INTRODUCTION

The protection of natural resources has become important to the people in the industrialised countries. In Germany it is ruled by three principles:

i) principle of "polluter pays" (Verursacherprinzip)
ii) principle of prevention (Vorsorgeprinzip)
iii) principle of co-operation (Kooperationsprinzip)

Principle of "polluter pays"

Anybody responsible for adverse environmental impact has to pay either for their avoidance or for counteracting the effects of any damage caused (Bundesregierung 1986). In Industry this principle was introduced to limit emissions of dust, chemicals, waste and noise. It has not yet been developed in Agriculture because the requirements of environmental protection are more difficult to define; the main problem being the assessment of damage, with respect to changes in the natural vegetation of arable fields following soil cultivation, drainage, fertilisation, and plant protection. Criteria for defining adverse effects cannot easily be found because of their often gradual impact, and the inter-dependent nature of the abiotic and biotic components of the environment. (Abiotic components soil, water and air will not be considered here.)

Economic pressures cannot excuse environmental impact. All areas of production and consumption are under such pressures. Industrial production is subjected to international competition without any EEC marketing guarantees but nevertheless has to comply with certain environmental restrictions (Heydemann 1983a). But in the Federal Nature Conservation Act it is stated that good agricultural practice and its associated pest control is not defined as a factor limiting nature and landscape. This agricultural clause causes much discussion in Germany, and its repeal is required by among others, the 'Council of Environmental Experts' who demand restrictions and guidelines on land use to reduce pressure on the environment. Chemical weed control is agronomically, a reasonable measure, yet there is no known environmental threshold at which "good agricultural practice" becomes "environmental impact". Therefore certain compounds must not be used for weed control and regulations have been introduced to ensure the environmental safety of crop production.

Principle of prevention

Taking actions to prevent environmental damage is also a political principle (Bundesregierung 1986). Research and Advisory Services, both of the State and of Industry are responsible for the development and dissemination of knowledge for legislation and its practical application. Man has had an impact on ecosystems by his very use of them. If irreversible damage is to be avoided, then ecosystem stability and the potential sources of stress must be evaluated, criteria of human impact developed, and proposals for the necessary limitation of risk found. This is a task of ecological research, and its results should be the basis of political decisions for adequate environmental protection (Becker 1987).

The high political importance of environmental protection has been expressed in increasing amounts of legislation in Germany especially in the 1970's when the protection of the total environment (Naturhaushalt) was demanded; for example the 'Federal Forest Act' (Gesetz zur Erhaltung des Waldes und zur Förderung der Forstwirtschaft, 1975), the 'Federal Nature Protection Act' (Gesetz über Naturschutz und Landschaftspflege, 1976, 1987), the 'Fertiliser Act' (Düngemittelgesetz, 1977) and the 'Chemicals Act' (Gesetz zum Schutz vor gefährlichen Stoffen, 1980) (Herfs 1982). In the latest 'Plant Protection Act' (Gesetz zum Schutz der Kulturpflanzen, 1986) the protection of the total environment (Naturhaushalt) has been especially highlighted. Here the term "Naturhaushalt" refers to the ecological system of soil, water and air as well as of plants and animals (noxious organisms, the targets of plant protection measures are exempted). The incorporation of this demand into the law has led to the introduction of further ecological testing. Moreover, this legislation now includes an extensive supervision of plant protection equipment. This regulation should help to diminish or to avoid unwanted side-effects e.g. phytotoxocity, unacceptable crop residues, drift, and unnecessary harm to wildlife.

Principle of co-operation

Improving environmental safety by the development of guidelines, legislation, advice, and its practical application in agriculture and landscape management is a public task which can only be solved by intensive co-operation and exchange of information between University Institutes, Federal and Industrial Research Centres, Advisory Services, Nature Conservation Authorities, and farmers.

IMPACT OF HERBICIDE USE ON ANIMATE COMPONENTS OF ARABLE FIELDS

Effect of chemical weed control on the weed flora

In central Europe the greatest diversity of species is found in cultivated landscapes not in "natural" ones. During the past 5000 years a diverse flora has developed which, in Germany, contains 2667 species (Sukopp *et al* 1978). Roughly 10% of them may occur as arable weeds of which only some 10% are the agronomically determined targets of weed control. Agricultural crops are grown in the Federal Republic of Germany on 7.2 million ha (29% of the total land area). More than 80% of this area is treated with herbicides annually (Hanf 1986) (Table 1).

There have been considerable changes in crop rotations because of effective and specific herbicides. Sugar beet may now be grown on fields formerly infested with *Agropyron repens*. Chemical weed control has enabled

TABLE 1

Estimate of chemical weed control in different arable crops in the Fed. Rep. of Germany (after Hanf 1986)

Crop	Percentage of total land area %	Percentage of crop treated with herbicides %
Winter cereals	13.0	95
Spring cereals	6.5	85
Maize	4.0	80
Sugar beets	2.0	98
Oil seed rape	1.0	98
Potatoes	1.0	50

farmers to grow maize on 1 million ha in Germany, equivalent to 14% of arable fields but atrazine-resistant plants have arisen in several species e.g. *Amaranthus retroflexus, Chenopodium album, Senecio vulgaris, Solanum nigrum* and *Stellaria media* (Kees 1978, 1986). Wheat monoculture has been practised for decades made possible by chemical weed control, and minimum tillage could only be practised with the use of effective herbicides.

Decline of arable weed species

Methods of weed control have always influenced their distribution; the most important development of which has been the expanding scale and diversity of herbicide use. The principal ecological effect of this has been to change the composition of weed populations on arable land (Fryer 1977). By 1962, there was already concern about the strong influence of the intensification of agriculture on the typical flora of arable fields which resulted in more simple plant communities (Tüxen 1962). This might have only concerned plant-sociologists if such changes did not disturb or destroy total agro-biocoenoses (Heydemann 1983a). Several German authors (Meisel 1977, Holzner 1978, Sukopp *et al* 1978, Schumacher 1980, 1987, Wilmanns 1984) also believe that herbicide use has been the major contributory factor in the decline of the diversity of the weed floras of arable land over the past 30 years. Herbicide efficiency affects the numbers of seeds individual plants return to the soil. After long-term and effective herbicide use one would expect to see a considerable reduction in density of weed populations and finally the possible elimination of species.

About one third of the 250-300 plant species potentially growing on arable land in Germany are listed in the Red Data Book of Endangered Plant Species (Blab *et al* 1984), 15 of them are considered to be either extinct or not recently observed, and 75 species are endangered to some extent (Eggers 1984). Fifty-five of these species belong to cereal plant communities, 29 among them to the basiphilic ones, 4 restricted to the growing of flax, and 3 typically growing on very light sandy soils. Twenty-three of the endangered species belong to root crop and vineyard communities, and 12 species, belonging to communities growing on temporarily wet arable fields.

Reasons for these declines cannot easily be identified, but it is thought to be due to a complex of factors determining their habitats. The former habitats which resulted in the occurrence of certain characteristic species and sociological groups have largely been improved to more uniform and productive levels suitable for today's agriculture. Among the species influenced by fertilisers are many very characteristic species e.g. *Caucalis platycarpos* on basic soils or *Arnoseris minima* on acid (sandy) soils (Eggers 1984). Better drainage has resulted in the decrease of those species found on soils at least temporarily wet on the surface. Of minor influence (in terms of number of species) have been factors such as seed cleaning, discontinuance of certain crops and intensification of soil cultivation. Half of the threatened weed species in Germany are at the limits of their distribution in this country. Such species are at particular risk from the competition of cultivated plants and from agricultural practices (Holzner 1978). As the typical species belonging to weed communities decline as a result of today's methods of cultivation and weed control, ubiquitous companion species (e.g. *Alopecurus myosuroides, Galium aparine, Matricaria spp., Mercurialis annua, Veronica spp., Viola arvensis*) have increased.

Conservation of threatened arable weed species

As arable weeds depend on regular cultivation of the land and quickly disappear from fallow land, they cannot be protected by usual conservation methods. As well as cultivation and seed storage of threatened species in botanic gardens or seed banks, it is even more desirable to preserve these species in the wild state in their particular habitats. To ensure their conservation, suitable management of at least parts of fields (along the margins or headlands) (Nezadal 1980, Schumacher 1980, 1981) is now being practised in different parts of Germany, Denmark and in Britain. These protected parts of fields may receive less fertiliser and will be kept free from herbicides. This conservation concept for arable weeds is ruled by the idea of linking agriculture and nature conservation in the same field (Schumacher 1980). It is of great merit that farmers and conservationists co-operate successfully and thus partly overcome their long standing differences. An important contribution has also been made by the shooting fraternity and their increasing support may be expected if the experiences in Britain become better known in Germany.

Special programmes are run by some Federal Länder. In Northrhine-Westphalia several hundred kilometers of protected headlands have been established. Since 1984 the Plant Protection Service of Rhineland-Palatinate has run a similar programme on more than 60 km field margins in which 243 arable species and 8 different plant communities have been found. Some species considered to be extinct (*Adonis flammea, Bromus grossus, Galium spurium*) or near to extinction (*Agrostemma githago, Fumaria parviflora, Nonea pulla*) were rediscovered in protected field margins (Oesau 1987). In Schleswig-Holstein, in 1986 an "extensification" programme was implemented including arable field headlands. Similar work is underway in Lower Saxony where several species near to extinction (*Adonis aestivalis, Bupleurum rotundifolium, Consolida regalis, Neslia paniculata* and *Scandix pecten-veneris*) were found. Farmers are very willing to participate in the field margin programme even without financial compensation (2.5 p m^{-2}), especially if they are hunters. These conservation projects are run in collaboration with individual botanists, Nature Conservation Societies and Authorities and partly together with Game Conservation Institutions and the Plant Protection Services to ensure proper recording of the results.

The conservation of endangered species may be one aim of the field margin concept (as practised in Lower Saxony) but the sovereign aim must be the preservation of characteristic plant communities (Oesau 1987) in order to establish an ecological network. Nature reserves for the protection of arable weeds are often called for, but are still unknown. Their conception and operation is a political question which cannot be solved without substantial financial support.

Effect of chemical weed control on the fauna

The impact of weed control results in decreases in density, biomass and, possibly even species of what is the primary food source of the fauna. In central Europe some 100 arable weed species are the host plants for ca. 1200 phytophagous species. The importance of a particular plant species differs widely (Table 2). Therefore the decline or loss of a plant species may have considerable "knock-on" effects on animal species at other levels of the food chain. According to the 12:1 ratio of phytophagous animal to weed species, a decrease of plant species density (diversity) could result in an even higher decrease of animal species (Heydemann 1983a), not only of phytophagous but also of detritophagous and carnivorous ones. The significance of flowering weed species for nectar and pollen feeding insects must also be considered (Haas 1982, Heydemann 1983a).

TABLE 2

Animal species specialised to feed on arable weed species in Germany (from Heydemann 1983a)

Weed species	Number of animal species	Weed species	Number of animal species
Agropyron repens	81	*Cerastium spp.*	37
Cirsium arvense	80	*Stellaria media*	36
Senecio spp.	76	*Anagallis arvensis*	6
Poa annua	41	*Chrysanthemum segetum*	4
Chenopodium spp.	51	*Euphorbia peplus*	3
Polygonum aviculare	40		

Most investigations on the effects of agricultural practices on the agri-fauna are short term. However, the results of a comparison of the species density and abundance of some benefical epifauna between 1951 and 1982 illustrated the impact of agricultural intensification (without drainage or consolidation) (Heydemann 1983a,b) (Table 3). The largest losses were recorded in row crops on sandy soil, with high losses also occuring in winter cereals. How much chemical weed control had been involved in these changes can only be supposed but, in contrast to 1951/52, it has subsequently become an important ecological factor in these agro-biotops (Table 1).

TABLE 3

Changes in the beneficial epifauna (Coleoptera, Formicidae) between 1951/52 and 1981/82 (after Heydemann 1983b)

Agro-biotop	Mean number of species		% loss	Mean number of individuals		% loss
	1951/52	1981/82		1951/52	1981/82	
Winter cereals						
on sandy soils	42	22	48	400	200	50
loamy soils	34	11	68	350	73	79
Row crops						
on sandy soils	27	4	85	200	38	81
loamy soils	24	11	55	230	63	73

Currently, the Institute for Biological Pest Control of the Federal Biological Research Centre is investigating the importance of boundaries and margins for the spread of benefical arthropods into fields and whether the establishment of field margins protected from pesticide use will support the conservation of other species. First results indicated that Carabidae overwintered in the boundaries and that untreated field margins favoured their dispersal into the field. As a consequence, aphid densities were reduced below the economic threshold, thus enhancing a more integrated control programme.

Direct effects of herbicides on the fauna appear to be relatively unimportant. Ecotoxicological investigations have usuallly been made on particular species of plants and animals. Therefore only limited information upon the behaviour and impact of chemicals in ecosystems is available. One-species tests may nevertheless be worthwhile for the assessment of risks to the environment if criteria for the evidence of such tests can be established (Becker 1987). From the beginning, the Plant Protection Legislation gave priority to the protection of plants and stored products; but it also allowed for future regulation concerning the protection of beneficial organisms useful in plant protection. The 'Bee Protection Ordinance' (Verordnung zum Schutz der Bienen vor Gefahren durch Pflanzenschutzmittel, 1972) led to the obligatory testing of all products for their effects on honeybees; an important step towards the consideration of environmental aspects in the official examination of pesticides in Germany. Currently, the Federal Biological Research Centre intends to introduce obligatory testing of all pesticides for their activity against beneficial organisms. For many years the Working Group "Pesticides and Beneficial Organisms" of the International Organization for Biological Control, West Palaearctic Regional Section (IOBC WPRS) has been developing test methods (Herfs 1982). These are used on a step-wise progression from laboratory to semi-field and to a field scale. Obligatory testing of all pesticides for their effects on earthworms as primary detritophages similarly to the current guidelines for *Eisenia fetida* (Riepert 1984) shall be introduced. For the Approval Procedure, data on the acute toxicity of commercial products to birds and fish have to be presented as a basis for an assessment of their likely impact.

The overwhelming importance of herbicides is their impact on wild floras and thus on the fauna indirectly, not only insects and other invertebrates but also birds, e.g. the grey partridge (*Perdix perdix*) which feeds its chick on insects (Potts 1986) or the corn bunting (*Emberiza corlandra*). This species has drastically declined in Germany due to the lack of dicotyledonous weed seeds in cereals (Blaszyk 1966). However, some species have been observed nesting in crops where they previously did not; e.g. oyster-catcher (*Haematopus ostralegus*) and lapwing (*Vanellus vanellus*) in sugar beet and potato fields, or marsh and Montagu's harrier (*Circus aeruginosus* and *Circus pygargus*) in cereal fields. Chemical weed control led to less disturbance by soil cultivation and mechanical weed control (Blaszyk 1975).

Side-effects of herbicides on soil micro-organisms

Higher plants contribute to the soil biocenosis by the nature of their communities, and by changing the microclimate, the fauna, and the availability of nutrients. All plant protection measures, whether physical or chemical alter the stands of crops or weeds, thus affecting soil micro-organisms. Because they occur in such very large numbers and because they also participate in a wide range of conversion reactions, micro-organisms are an important component of the soil ecosystem and determine soil fertili-

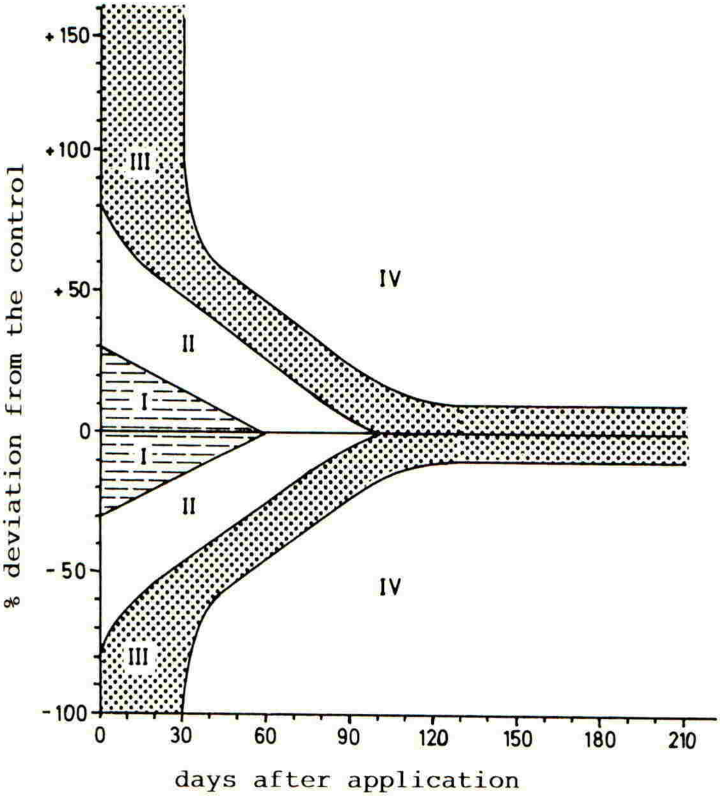

Fig. 1. Assessment of ecotoxicological effects of pesticides on soil micro-organisms (from Anderson *et al* 1987)

ty. The better knowledge of soil biology and of the importance of soil micro-organisms, more sophisticated methods of research, as well as the increase of chemical pest control resulted in an increasing literature about side-effects of pesticides on soil micro-organisms and their functions. Up to 1984/85 Malkomes (1985) found more than 3500 original papers (and more than 400 reviews), nearly 2/3 (1/2) of which dealing with the influence of herbicides. The number of herbicide papers doubled from 1971 to 1980, compared to the previous decade.

Since 1970, studies of microbial activity have taken preference over those on microbial populations. Ecotoxicological investigations should cover the total ecosystem, but this is an almost impossible task. Investigating effects on important transformation activities in the soil include straw decomposition, respiration, ammonification and nitrification. Dehydrogenase activity and respiration are indicators for overall microbial activities. Respiration rate and ATP content may also be taken as a measure of the microbial biomass in soil (Malkomes & Wöhler 1983). Studies must look not only to the effects of pesticides on biological activities but also to their duration. In laboratory trials Malkomes & Wöhler (1983) found marked inhibitions several months after application, although most of the chemicals had disappeared from the soil.

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Effects of pesticides on micro-organisms must be considered to be similar to natural phenomena. Assuming a normal doubling of the soil microflora within 10 days, an ecologically tolerable recovery period of 20-30 days at 15°C may be assumed (Domsch *et al* 1983). Malkomes (1985) has developed a concept for the assessment of effects of pesticides on soil micro-organisms. Presuming that any influence should not last for longer than 3 months (thus having a regard for the following crop within a rotation), this time limits the critical period. The assessment concept includes all deviations from the control, not only inhibitions but also stimulations which may result from effects on the microbial biomass. Malkomes' (1985) assessment concept was incorporated as the basis for the official examination of pesticides according to the recent 'Guidelines on effects on activities of the soil microflora' (Anderson *et al* 1987) (Figure 1); at first the influence on respiration and dehydrogenase activity has to be studied, but further studies may be necessary according to their percentage of deviation in the I, II, III, or IV area. The examination of side-effects of pesticides on soil microorganisms is another step towards the consideration of environmental aspects in the Approval Procedure in the Federal Republic of Germany.

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SELECTIVE GRASS WEED CONTROL IN CEREAL HEADLANDS TO ENCOURAGE GAME AND WILDLIFE

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ABSTRACT

Nine experiments were conducted over 2 years to investigate the potential for selective chemical control of black-grass (Alopecurus myosuroides) in winter cereal headlands, as part of the Cereals and Gamebirds Research Project's "conservation headlands" initiative. The aim was to allow the survival of certain broadleaved weed species which are host plants for insects eaten by gamebird chicks. In six of seven experiments with high populations of A. myosuroides, diclofop-methyl gave greater than 90% control. A sequence of tri-allate followed by diclofop-methyl gave more than 98% control in six of seven experiments. These figures compare favourably with the performance of traditional control materials. The tri-allate/ diclofop-methyl sequence had little or no effect on most of the desirable broadleaved weed species present. In addition, a useful measure of Galium aparine control was achieved by tri-allate, in two experiments where this weed was present. Chlortoluron generally controlled A. myosuroides and susceptible broadleaved species well, but effects of isoproturon were variable.

INTRODUCTION

Since 1983 the Cereals and Gamebirds Research Project has been studying the side-effects of pesticides on non-target species, and developing methods of alleviating such effects within the context of modern farming systems (Oliver-Bellasis & Sotherton 1986). One such method is to modify pesticide input over a 6m wide band of crop at the edge of cereal fields to promote the survival of certain broadleaved weeds and their associated insect fauna. The resulting increases in populations of wild gamebirds (Rands 1985, 1986, in press), butterflies (Rands & Sotherton 1986) and other insects (Sotherton et al 1985) are now well documented. More recently, potential benefits to small mammals and rare arable weeds have become apparent (Tew 1987, Wilson 1987). The technique has already been adopted in West Germany and other European countries for the conservation of the rarer components of the arable flora (Schumacher 1987).

In developing such a system, now known as "conservation headlands", the aim has been to cause the minimum impact on crop production commensurate with the benefits to be obtained. A particular concern of farmers is to ensure that headlands do not become infested with certain pernicious weed species, especially black-grass (A. myosuroides), wild-oats (Avena spp.), barren brome (Bromus sterilis) and cleavers (G. aparine) (Bond 1987). Such species are often most abundant at the edges of fields (Marshall 1985), and it has been suggested that it may often be cost-effective to apply sequential herbicide treatments to headlands for their control (Roebuck 1987).

It has therefore been necessary to develop herbicidal options against the major grass weeds and G. aparine which would give a high degree of control yet have minimal effect on the more desirable weed species, including knotgrass (Polygonum aviculare), black-bindweed (Fallopia convolvulus), common chickweed (Stellaria media), mayweeds (Matricaria spp.), fat- hen (Chenopodium album), charlock (Sinapis arvensis), hemp-nettles (Galeopsis spp.) and field pansy (Viola arvensis). Many herbicides commonly used to control Avena spp. are selective in their action, but control of other grass weeds traditionally involves the use of chemicals with broad-spectrum activity. Preliminary studies of alternative options for control of A. myosuroides are described in this paper.

MATERIALS AND METHODS

In autumn 1985 experiments were established in the headlands of 4 commercial winter cereal crops to study the potential of tri-allate and diclofop-methyl, alone or in sequence, as selective treatments for A. myosuroides control in comparison with the "standard" chemicals chlortoluron and isoproturon. In 1986/87 two further experiments were carried out in winter wheat headlands to examine a wider range of treatments, including two new chemicals, imazamethabenz and FD 4026 (ICI Plant Protection). Additional information on control of some broadleaved species was obtained from two further experiments.

TABLE 1

Site and crop details for A. myosuroides control experiments

Experiment	Site	Soil	Crop	Cultivar	Cultivations	Drilling date	Previous crop
1985/86							
1	Balsham Cambridgeshire	clay	barley	Halcyon	tine	8 Oct.	wheat
2	Balsham	clay	wheat	Avalon	tine	31 Oct.	wheat
3	Basingstoke Hampshire	clay loam	wheat	Brimstone	plough	17 Oct.	wheat
4	Kineton Warwickshire	clay	wheat	Mission	plough	17 Oct.	wheat
5	Ixworth Thorpe Suffolk	sandy clay loam	wheat	Galahad	plough	24 Oct.	wheat
6	Balsham	clay	wheat	Galahad	plough	17 Oct.	beans
1986/87							
7	Balsham	clay	wheat	Galahad	plough	6 Oct.	wheat
8	Basingstoke	clay loam	wheat	Rendezvous	plough	10 Oct.	beans
9	Ixworth Thorpe	clay loam	wheat	Avalon	plough	10 Dec.	sugar beet

All experiments were laid out in a randomised block design with four replicates. Plots were situated between the field boundary and the first tramline. This distance was 6m (12m at the Cambridgeshire site). Plot width was 3.6m (6m in Cambridgeshire (1986)). Details of sites and crops are shown in Table 1. Herbicide application timings are shown in Table 2.

TABLE 2

Herbicide applications dates and growth stages[1] of A. myosuroides and crop at spraying.

Herbicide	Application	Crop G.S.	A. myosuroides G.S.
1985/86			
tri-allate	4-29 Oct.	pre-emergence	pre-emergence
isoproturon	31 Oct.-12 Dec.)	pre/early	pre/early
chlortoluron	31 Oct.- 8 Dec.)	post-emergence	post-emergence
diclofop-methyl	27 Jan.-21 Mar.	20-22	12-14/20(-21)
1986/87			
tri-allate	16 Oct.- 4 Nov.	pre/early post-emergence	pre/early post-emergence
isoproturon (early treatments)	16 Oct.- 4 Nov.	pre/early post-emergence	pre/early post-emergence
isoproturon (late treatments)	16-22 Dec.	12-13/20-24	13-14/20-21
imazamethabenz	21-28 Nov.[2]	12-13	pre/early post-emergence
diclofop-methyl) FD 4026)	7 Jan.- 6 Feb.[2]	20-24	13-14/20-21

[1] Zadoks et al (1974)

[2] In Experiment 3 drilling was delayed due to late harvest of previous crop. Applications of some herbicides were therefore made much later to coincide with correct crop/weed growth stages. Imazamethabenz was applied on 20 March, and diclofop-methyl and FD 4026 on 23 April.

Herbicides were applied with knapsack sprayers fitted with a 3m boom and 120° flat-fan nozzles (Experiments 1 and 2, 1986). or 1.8m boom and 80° nozzles (others). Spray pressures and volume rates followed manufacturer's recommendations. Tri-allate was applied to Experiments 1 and 2 as a liquid immediately after drilling and incorporated with a power harrow. In all other experiments tri-allate was broadcast in granule form using a "pepper-pot" technique. In all cases, fertiliser and fungicides were applied by the farm as for the rest of the field.

Grass weeds were counted in April or early May and broadleaved weeds in May or early June. Ten 0.25 or 0.1m^2 quadrats (depending on the density of the infestation) were assessed per plot. Grass seedheads were counted in late June/early July using "floating" lathe quadrats (ten 0.25m^2 quadrats per plot).

RESULTS

In 1985/86 the tri-allate/diclofop-methyl sequence gave consistently high levels of reduction in seedhead numbers, generally equivalent to those achieved by chlortoluron and often superior to isoproturon (Table 3). Control by diclofop-methyl alone was greater than 90% in four experiments but only 69% in the other. However, the average performance was better than isoproturon. Tri-allate alone produced useful levels of control but generally lower than other herbicides.

TABLE 3

Percentage control of A. myosuroides seedheads by various herbicide treatments, 1985/86.

Treatment	Dose (kg a.i. per ha)	Experiment 1	2	3	4	5	Mean
tri-allate	2.25	44	70	92	89	88	77
diclofop-methyl	1.14	92	98	94	69	99	90
tri-allate + diclofop-methyl	2.25) 1.14)	92	99	100	98	100	98
isoproturon	2.10	-	-	-	-	97	
isoproturon	2.50	83	92	54	100	99	85
tri-allate + isoproturon	2.25) 2.50)	98	-	-	-	100	
chlortoluron	2.50	-	98	94	100	-	97
chlortoluron	3.50	96	100	97	100	-	98
Seedheads m^{-2} in unsprayed treatment		182	147	1056	110	219	

A. myosuroides populations in the 1986/87 trials were lower than in the previous year, and control levels were high throughout (Table 4). Diclofop-methyl at 1.14 kg a.i. ha^{-1}, alone and in sequence with tri-allate again performed well. Diclofop-methyl at 0.76 kg a.i. ha^{-1} with "Galion" surfactant also gave good control, as did diclofop-methyl at 0.57 kg a.i. ha^{-1} in sequence with tri-allate. FD 4026 gave promising results, as did imazamethabenx. The latter chemical is not claimed to give complete control of A. myosuroides (Anon, 1986a), but could be useful in sequence with other products.

In both years the sequence of tri-allate and isoproturon gave very good control of A. myosuroides in the 3 experiments in which the treatment was included (Tables 3 & 4). Reduced rates of chlortoluron (Table 3) and isoproturon (Tables 3 & 4) performed similarly to the recommended rates for A. myosuroides control.

Neither diclofop-methyl nor FD 4026 significantly affected any broadleaved species present in trials. Imazamethabenz reduced numbers of scarlet pimpernel (Anagallis arvensis) by 66% in Experiment 9, following application in March, but did not affect any other broadleaved species. No reduction in numbers of G. aparine due to this chemical was observed in

Experiment 7, where this species was moderately abundant (5 plants m^{-2} in unsprayed plots).

TABLE 4

Percentage control of A. myosuroides seedheads by various herbicide treatments, 1986/87.

Treatment	Dose (kg a.i. per ha)	Experiment 7	Experiment 8	Mean
diclofop-methyl	1.14	100	92	96
diclofop-methyl + surfactant	0.76) (0.5)[1])	99	96	97.5
tri-allate + diclofop-methyl	2.25) 1.14)	100	99	99.5
tri-allate + diclofop-methyl	2.25) 0.57)	98	98	98
isoproturon (early)	2.50	92	97	94.5
isoproturon (early)	2.10	96	-	
isoproturon (late)	2.50	99	100	99.5
tri-allate + isoproturon	2.25) 2.50)	-	100	
imazamethabenz	0.50	92	78	85
FD 4026	(3.0)[1]	87	100	93.5
Seedheads m^{-2} in unsprayed treatment		99	70	

[1] litres ha^{-1} product

TABLE 5

Percentage control of broadleaved weeds by residual grass weed herbicides

	Chlortoluron A	Chlortoluron B	Isoproturon A	Isoproturon B	Tri-allate A	Tri-allate B
Anagallis arvensis	-	-	1(0)	-	1(1)	65
Fallopia convolvulus	3(2)	94(92-96)	3(0)	-	3(0)	-
Chenopodium album	1(0)	-	2(1)	94	2(0)	-
Galium aparine	1(0)	-	2(0)	-	2(2)	69.5(69-70)
Matricaria spp.	2(2)	88(77-99)	3(1)	100	3(0)	-
Myosotis arvensis	1(1)	100	2(0)	-	2(0)	-
Polygonum aviculare	3(3)	89(68-100)	2(0)	-	3(0)	-
Stellaria media	-	-	1(1)	79	1(0)	-
Veronica spp.	2(1)	83	5(1)	72	5(5)	81(64-98)

A = no. of trials with number showing significant control in parentheses (only levels of control significant at $P<0.05$ are shown: analysis of variance carried out on plant numbers or $\log_e(x+1)$ plant numbers).
B = mean % control with range in parentheses

Chlortoluron greatly reduced or eliminated populations of F. convolvulus, P. aviculare, Matricaria spp., forget-me-not (Myosotis arvensis) and speedwells (Veronica spp.) where these species were present (Table 5). Isoproturon was much more variable in its effects, giving high levels of control of Matricaria spp., C. album, Veronica spp. and M. arvensis in some trials, but little or none in others. Control was poorer in experiments where crops were thin, though observation suggested that weeds of susceptible species in isoproturon-treated plots were often smaller than in untreated plots. Reduced rates of chlortoluron and isoproturon gave similar levels of broadleaved weed control to full rates (data not presented).

The only broadleaved species affected by tri-allate were A. arvensis, Veronica spp.), and G. aparine. Numbers of Veronica spp. (mainly V. persica and V. arvensis) were greatly reduced by tri-allate in all 5 trials where they occurred. In the two trials where G. aparine was present, tri-allate gave around 70% control of this species.

DISCUSSION

The results indicated that a single application of diclofop-methyl presented a viable alternative approach to traditional chemicals for A. myosuroides control on cereal headlands, particularly when used in sequence with tri-allate. Flint (1985) obtained 75-97% control of A. myosuroides in 6 trials with diclofop-methyl at 1.08kg a.i. ha^{-1}. Results with lower rates were poorer and more viable. A sequence of tri-allate followed by diclofop-methyl at 0.54 kg a.i. ha^{-1} gave levels of control between 68 and 94%. A tri-allate sequence with diclofop-methyl at full rate was not tested.

In the present trials, the primary consideration was the very high level of control required to counteract the poorer conditions and high weed populations commonly associated with headlands. Cost was considered to be of secondary importance, in view of the small area involved. Accordingly, chemicals were generally applied at the recommended rates for A. myosuroides control, even where sequences were used. In the few cases where reduced rates were included for comparative purposes however, neither control of A. myosuroides nor broadleaved species was significantly affected. Similarly Flint (1985) found that isoproturon at 2.0kg a.i. ha^{-1} was as effective as 2.5 kg a.i. ha^{-1}.

Control of both A. myosuroides and broadleaved weeds by isoproturon was very variable, particularly in the 1985/86 trials. Similar results have been blamed on a build-up of ash residues from straw-burning in minimum cultivation systems (Flint 1985), but this is unlikely to be a factor in these experiments. Isoproturon is known to be less persistent in the soil than chlortoluron, and its persistence is further reduced when a prolonged period of wet weather follows application as it did in autumn 1985 (Luscombe 1983). Hewson & Read (1985), summarising trials carried out over 11 years, reported that control of A. myosuroides by isoproturon was poorer in years with wet autumns. Furthermore, headland conditions are often not ideal for the action of soil-applied herbicides, due to soil compaction, formation of clods, and less competitive crops (Roebuck 1987). The very poor control of A. myosuroides in Experiment 3 is probably the result of a thin, uncompetitive crop. Black-grass is strongly influenced by crop plant density: in a thin crop, its tillering capacity is greatly enhanced (Moss 1980).

The effect of isoproturon on broadleaved species present in the spring was even more variable, control of some species ranging from 0-100% in different trials: tri-allate was much more consistent. The persistence of isoproturon over winter varies depending on rainfall, whereas tri-allate is unaffected (Luscombe 1983). The survival of spring-germinating seedlings following autumn isoproturon depends on the competitive ability of the crop as well as residual herbicide activity. Under suitable conditions however, resistant species (e.g. P. aviculare) may benefit from removal of competition by other weeds (unpublished data). Conversely, where the weed flora is predominantly composed of susceptible species (eg. S. media, Matricaria spp.), weather conditions are favourable, and/or a vigorous crop in present, few "desirable" weeds may remain.

Diclofop-methyl appears to have several advantages in the context of conservation headlands. It is totally selective, having no effect on non-target species. Being a foliar-acting herbicide, it is unnaffected by soil conditions, and it works without the need for crop competition (Anon, 1986b). The main disadvantage of diclofop-methyl is the need for timeliness of application at a difficult time of year. Seedlings must be emerged at spraying, but the chemical is only effective when applied before tillering. This generally implies application in the middle of winter, when very few "spray days" are available (Spackman 1983). Early application of tri-allate is therefore a useful insurance measure. An added benefit of using tri-allate is the very useful degree of G. aparine control exhibited by this chemical. Unfortunately it also controls Veronica spp., but these are among the less valuable species as hosts for insects eaten by gamebird chicks, although they can be useful nectar sources for butterflies.

Another interesting possibility is enhancement of the activity of diclofop-methyl against older A. myosuroides plants by addition of an adjuvant. Ayres (1987) has obtained good control of A. myosuroides with several tillers in this way. In the current trials good control was achieved by diclofop-methyl at 0.76 kg a.i. ha^{-1} plus "Galion" surfactant, applied at the 3-4 leaf stage, but later applications were not investigated.

New chemicals with selective modes of action may increase the options available. Both FD 4026 and imazamethabenz are promising candidates for increasing the flexibility of selective control programmes, but current data is limited and more work is required. It is to be hoped that the recent increase in new products with a selective mode of action will continue and that agrochemical companies will not be tempted to release such chemicals only in mixtures with other broad-spectrum compounds.

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THE ENVIRONMENTAL IMPACT OF BRACKEN

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ABSTRACT

Bracken is an opportunistic pioneer which has exploited historical changes in land use and become one of the most successful weeds in the British Isles. It is currently spreading at the rate of 1-4% per annum. The consequence of lost grassland and moorland is a reduction in grouse and sheep productivity and ultimately the sale of land to the alternative land use of afforestation.

In conservation terms bracken carries fewer birds, mammals and insects than the ground it replaces and can introduce parasites harmful to sheep and grouse. The future role of using a biological control to control bracken or the idea of harvesting bracken as a biofuel is summarised.

INTRODUCTION

In the ecological sense, bracken (Pteridium aquilinium) is a remarkably successful weed. It is tolerant of a wide band of climatic conditions, it is physically and biochemically unpalatable, it is highly resistant to diseases, it releases allelopathic compounds thereby inhibiting the growth of other species and with its highly developed and effective rhizome system it spreads quickly, has a long life expectancy and can withstand severe burning (Page 1986). Clearly bracken exhibits the characteristics of a highly adapted opportunistic pioneer and it is perhaps not surprising to discover that it has exploited ground disturbed by man and his livestock and so become a highly successful weed.

Although bracken is considered the most widespread vascular plant in the world it would seem that there are few places where it is grows so vigorously and densely as it does in northern and western Britain. There is no doubt that this weed has caused serious loss of agricultural land and continues to encroach on threatened habitats while possessing features which cause problems with land management. Environmentally its only saving grace is that it turns to a golden brown in the autumn and appears aesthetically pleasing to the tourists which flock to Britain's upland areas. While extensive research on bracken continues around the world there are still problems with effectively controlling the weed. In this short paper I wish to evaluate the impact of bracken on the uplands of Britain (Figure 1) by considering the historical spread of the weed and the consequences of this, both directly and indirectly, on land use and upland conservation.

The history of bracken encroachment

At all localities within the British Isles where the rate of bracken encroachment has been monitored it is spreading and not receding. For Great Britain, the overall rate of encroachment has been estimated as 2.8% per annum (Taylor 1986), a rate which would result in an area the size of England being obliterated by bracken within a century. While the likelihood of such an event is negligible it is important to realise the

Fig. 2. Principal upland areas where bracken is considered a problem and conflicts with land use, based on Birnie & Miller 1986, Hudson 1986b and Taylor 1986. The 400 metre contour is shown as a dotted line.

scale of the problem; the rate of expansion is equivalent to the spread of forestry and urban development. Taylor (1986) emphasised this by pointing out that for every 4 hectares of farmland lost to forestry and urban development an area of between 1 to 2 hectares is lost to bracken.

We know from the examination of spore records that bracken was widely distributed in the British Isles during Mesolithic times although it was probably a minor component in the natural woodland vegetation. Some 5000 years ago as Neolithic man reduced the extent of this natural woodland and the climate became more oceanic then bracken increased, particularly in areas cleared by man where the competitive ability of the trees was reduced and the bracken could invade the disturbed ground. Coupled with felling there was a steady increase in stump removal as the ground was ploughed while the incidence of fires increased and grazing pressure prevented tree regeneration. Within the past century the rate of bracken spread has accelerated as increased sheep grazing has selectively reduced the competitive ability of the more palatable grasses and produced a vacuum within which bracken could increase; the vicious circle of increased grazing pressure on smaller bracken-free areas has continued to exacerbate the problem. Furthermore, since the last war man's persecution of bracken has decreased as it is no longer cut for bedding, fuel or used in the manufacture of soap. Over the same time there has been a fall in management inputs into the uplands, abandoned areas of cultivation around crofts have allowed bracken to spread and the reduced numbers of keepers and shepherds have often resulted in poor burning practices on hill ground which has allowed the rapid expansion of bracken. In recent years it is possible that increased acid deposition and drainage have improved conditions for bracken and assisted with an accelerating rate of spread. In short, bracken spreads principally because it is an aggressive competitor and has expanded its range as it has taken advantage of natural and man-induced changes in land use.

Vegetation loss and consequences for land use

Bracken tends to favour areas of acidic grassland and heather while avoiding the water-logged blanket bog and the less acidic limestone areas. Consequently, the traditional site for bracken has been the steep sides of moorland hills. In recent years the conditions for bracken have improved on some of the flatter areas where it has a far greater impact on farming and conservation interests. On hill ground the benefits from spraying are marginal, even when additional stock is available to utilise improved areas. In areas like the North York Moors, some two-thirds of the bracken ground is on the heather moorland where it is currently encroaching onto the flatter tops and reducing feeding areas for sheep and grouse.

The viability of many upland estates depends on the availability of a good and well managed heather sward. Over-grazing of the heather by sheep and the expansion of bracken have reduced the area of suitable feed and productivity of some moors for grouse and sheep. For a grouse moor to break-even financially it must harvest 30 grouse per square kilometre. In 1980, in the North York Moors when 20% of the moorland was covered in bracken the average bag was 40 per square kilometre (Hudson 1986a). Any further decline in the size of the harvest, brought about by reduced management and/or a further spread of the bracken could be sufficient to reduce the harvest below the point where upland estates were viable. When this occurs land owners are forced to sell and with current tax incentives we can expect much of this ground to be sold for afforestation. In conservation terms, the replacement of heather moorland by large scale planting is considered disastrous since most of the upland fauna is lost and the moorland habitat becomes fragmented into ecologically small units.

Direct impact and conservation value of bracken

Bracken is of low conservation value. In moorland areas only 15 species of bird breed in bracken, while 33 regularly breed on heather moorland and 25 on the acidic grasslands that the bracken has replaced (Ratcliffe 1977). There are no specialist bracken breeding birds and amongst the 18 species lost from moorland when covered in bracken are some nationally important species such as hen harriers (Circus cyaneus), greenshank (Tringa nebularia) and twite (Carduelis flammea). Although it can provide cover for nesting birds the bracken fronds do not reach a suitable height until most birds have finished breeding and this is no doubt part of the reason why less than half the birds recorded in heather use bracken.

Some birds, like the black grouse (Tetrao tetrix), will nest in bracken although the bracken replaces their more favoured habitats such as blaeberry (Vaccinium myrtilus) and the encroachment of bracken into small birch plantations may have also resulted in a reduced density of black grouse. It is more than likely that most birds selectively avoid bracken stands although the evidence for this is lacking. Only during periods of hot weather in late summer or when being chased by predators do birds utilise the bracken for cover.

In the North Yorkshire Moors, Brown (1986) has recorded the abundance of invertebrates in bracken and from neighbouring heather dominant vegetation. In all instances the abundance of invertebrate groups is lower in bracken ground and increases after spraying and restoration of heather moorland. Coleoptera were more abundant on sprayed bracken and burnt heather, while both the ants and harvestmen were correlated with the extent of heather. Representation of taxonomic groups was the same in bracken both sprayed and unsprayed and there was quite simply an increase in abundance of insects with the abundance of heather.

For the invertebrate predators, the bracken ground is of low productivity compared to neighbouring heather moorland. Consequently it is not surprising to find that the invertebrate predators, such as the small mammals (Brown 1986) are at a lower density within bracken ground. This could also account for why some of the insectivorous birds such as the wheatear (Oenanthe oenanthe) appear to actively avoid bracken beds (Ratcliffe 1977).

Indirect impact of bracken on wildlife

Probably the largest environmental impact of bracken is that it quite simply replaces vegetation favoured by man and wildlife. In addition to this bracken has toxic properties which causes bright-blindness in sheep and staggers in horses. It is also carcinogenic and produces a type of leukaemia in cattle and stomach cancer in ruminants. Furthermore bracken provides a favourable habitat for parasites harmful to grouse and sheep.

The sheep tick Ixodes ricinus, is an ectoparasite of grouse and sheep that transmits a number of harmful diseases including louping-ill, tick borne fever and tick pyaemia. The indirect effects (as disease vectors) of ticks are known to be harmful to grouse and sheep and it is quite conceivable that they also influence a wide range of other animals. While not on their hosts the ticks require a humid habitat in which to survive and this is provided by the thick mat layer associated with rough grasslands and bracken. Through a questionnaire survey followed up by field studies Hudson (1986b) found a close association between moorland areas with tick problems and with extensive bracken beds. Bracken ground carried significantly more ticks than heather ground and grouse chicks utilising the bracken ground carried larger infestations. Treatment of the bracken with the herbicide asulam (May & Baker) reduced the thickness of the mat layer and the tick population and consequently the probability of tick borne diseases.

Bracken control and the future

The economic and environmental consequences of bracken are considerable. By replacing vegetation of importance to farmers and land owners and causing indirect damage to wildlife the spread of bracken is pushing our traditional forms of land use nearer the edge of financial loss and the ultimate change of multiple land use (sheep, deer, grouse, conservation and tourism) to the single land use of afforestation. It is important to realise that the bracken, often associated with over grazing (Hudson, 1984), is a major force causing this switch in land use. In this respect it is surprising that with a weed of such significance to this country there are no accurate figures on the actual expense imposed by the spread of bracken (Heads and Lawton 1986). Without doubt it must be several million pounds per annum and when everything is taken into consideration probably tens of millions of pounds. Agriculturally and environmentally we need an effective method of control.

At the current time most bracken is treated with the herbicide asulam. While effective when applied correctly it must be sprayed from a helicopter with follow-up treatment such as spot spraying or crushing, labour intensive and expensive techniques. Far too often large areas of bracken are efficiently sprayed but the follow-up costs are too high to instigate on a large area so the bracken rapidly regenerates from the rhizome system and returns the bracken to its previous state.

Alternative suggestions for reducing the spread or at least providing better control have included using the bracken as an energy crop. Lawson et al (1986) provide a refreshing and alternative approach to the more typical negative view of bracken by proposing its use as a biofuel and even suggesting that its exploitation could be a more profitable form of land use in the uplands than traditional sheep farming. Bracken as a biofuel is biologically and technically feasible and close to financial viability although many of the assumptions still require to be tested on a commercial scale.

Alternative control techniques include the development of effective biological controls. In Britain the bracken appears to have relatively few enemies while in other parts of the world there are at least two species of moth whose caterpillars are known to damage bracken either by directly eating the pinnae or penetrating the plant's rachis (stem). Obviously great care must be taken before biological controls are released although an assessment of Parthenoides indicates that this could well be a suitable candidate since it eats nothing but bracken (Lawton 1986). Even so, under the Wildlife and Countryside Act it is difficult to see what evidence should be collected for and against the release of a biological control for a natural weed. The implications of the debate about the introduction of a biological control are interesting and could have far reaching repercussions to other systems where genetically engineered viruses or other pests could be introduced.

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HERBICIDE EFFECTS ON THE FLORA OF ARABLE FIELD BOUNDARIES

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ABSTRACT

Studies of field boundary floras under the Boxworth Project have continued for four seasons. Data from broad-scale surveys and detailed studies of limited areas indicated some changes in field edge flora. These did not correlate with intensity of herbicide use in adjacent fields, suggesting other factors, particularly close cultivation, were important in botanical change in field edges. Records of floras adjacent to unsprayed or "conservation" headlands on the Manydown Estate initially demonstrated a trend for increased plant diversity compared with sprayed headlands, but this was not confirmed. Experiments on the susceptibility of hedgerow plant species have shown the spectra of activity of a range of herbicides and plant growth regulators. Many species might be affected by accidental contamination from over-spraying or spray drift, particularly by mecoprop, fluroxypyr, metsulfuron-methyl and glyphosate.

INTRODUCTION

Field boundaries are increasingly viewed as refuges for wildlife in intensively-managed farmland. Concern over the impact of agricultural operations, particularly agrochemical applications, on the ecology of the field boundary habitat has, therefore, increased. Under arable regimes, the requirement for retaining stock has largely gone, which in the past resulted in some farmers viewing hedges as undesirable (Grigor 1845). The view that weeds and other pest organisms spread from the field boundary has been held for many years and is widespread today. These perceptions have contributed to unsympathetic management of this habitat. Recent studies, however, have indicated that weed spread from hedgerows is limited to a few species and that beneficial fauna are found in the field boundary (Marshall & Smith 1987).

Arable hedgerows have been the main subject of field margin studies by Long Ashton Research Station as they are the most complex and diverse boundary structures. Herbicides may affect floras following accidental or deliberate over-spraying or from drift. Little data is available on the extent of such effects or the susceptibility of hedgerow plants to herbicides. Field observations on boundary floras where herbicide applications in the adjacent fields have been manipulated are reported in this paper. Changing herbicide use may result in more or less contamination of the field boundary and changes in the composition of field edges. The data form part of two larger research programmes, the Boxworth Project (Hardy 1986) and part of the Cereal & Gamebirds Research Project (CGRP) conducted on the Manydown Estate (Rands 1985). Investigations of the effects of direct applications of some herbicides and plant growth regulators on hedgerow plant species have produced relative information on susceptibilities and the likely impact of field rate applications of chemicals (Marshall & Birnie 1985).

BOUNDARY FLORAS OF FIELDS WITH CONTRASTED HERBICIDE USE

Boxworth

Fields at the Boxworth Experimental Husbandry Farm (EHF) are presently receiving three levels of pesticide input as part of a multi-disciplinary research programme, known as the Boxworth Project (Marshall 1985; Hardy 1986). Winter wheat fields within the Full Insurance area have received on average 5.4 herbicide applications per year between 1984 and 1986, the first three seasons of treatments. In contrast, Supervised area fields have had an average of 3.4 applications and Integrated area fields have had 2.7 applications each year. Detailed investigations of the flora were made in four 50m sections of boundary, with one site in each of the Full Insurance and Integrated areas and two (A & B) in the Supervised area. Extensive surveys were made by recording species present at fixed points 50m apart round the perimeter of all fields where a boundary structure existed. Numbers of species, their frequency at survey points per field and Margalef's index of species diversity (Margalef 1951) were calculated. However, the indices did not allow valid comparisons between fields, as the numbers of sampling points were not equal. Nevertheless, trends over time within areas and individual fields are meaningful.

A quantitative estimate of individual species within boundary lengths with uniform structure and aspect has also been made for all study fields at Boxworth. A domin scale (0-6) of species cover and abundance (Greig-Smith 1964) has been used in early summer for three seasons. Detailed transect assessments of vegetative frequency from within the boundary into the crop edge have been made in four 50m lengths of boundary. In July each year, species were recorded in eleven 10cm wide transects, each divided into 10cm lengths and running from within the boundary 5m into the crop. Numbers of species in the boundary out to the crop edge (Boundary) were compared with numbers found within the crop (Crop). Using percentage frequency data for each species, the Shannon-Weaver diversity index (H') was also calculated (Pielou 1966).

Boxworth Results

Extensive surveys of species composition in the boundaries of the three treatment areas at Boxworth have shown annual changes in species numbers and in Margalef's index of diversity (Table 1).

TABLE 1.

Numbers of species found and Margalef's index of diversity in each treatment area, Boxworth 1983-1986.

Area	Number of sites	Number of species				Diversity index			
		1983	1984	1985	1986	1983	1984	1985	1986
Full Insurance	95	98	97	109	83	13.7	13.0	14.7	11.3
Supervised	88	87	80	100	83	12.3	10.8	13.5	11.3
Integrated	76	81	87	95	73	11.9	12.0	13.1	10.3

Numbers of species and diversity indices in 1983, before treatments began, varied with number of sampling points. Thereafter, changes were not consistent, though the diversity and species number in the Full Insurance area became similar to those of the Supervised area. This might indicate a relative reduction in diversity within the Full Insurance area. Mean numbers of plant species at each sampling point are given in Table 2. These data did not correlate well with differences in herbicide use between the treatment areas.

TABLE 2

Mean number of species per sampling point in different treatment areas, Boxworth 1983-1986.

	Number of species per point			
	1983	1984	1985	1986
Full Insurance	12.7	16.6	16.2	15.3
Supervised	12.7	17.6	17.7	16.5
Integrated	10.7	16.9	16.9	14.7

The number of species, excluding shrubs, in uniform hedgerow sections of approximately even length (c. 300m) in four fields and recorded in June for four years are given in Table 3. No major changes associated with field treatments were evident in either annual, perennial or biennial species. The Full Insurance field showed few changes in annual or perennial species numbers. Declines in perennial and biennial species in the Supervised (A) field in 1985 and 1986 were followed by increases in 1987.

TABLE 3

Numbers of ground flora species in uniform hedgerow lengths of c.300m from four fields, Boxworth 1984-1987.

Field	Full Insurance				Supervised (A)				Supervised (B)				Integrated			
	84	85	86	87	84	85	86	87	84	85	86	87	84	85	86	87
Life form																
Annuals	5	4	5	3	10	3	6	6	4	7	7	2	12	6	5	8
Others	14	15	13	15	29	23	17	30	13	17	17	16	15	13	15	17

In each of the 50m intensive study sites, transects traversing the boundary and extending 5m into the crop were examined in July. Results were expressed as numbers of species, including shrubs, found in the boundary and in the crop and as the Shannon-Weaver diversity index (Table 4). The mean lengths of sample transect in the boundary or crop areas are also given. There were generally fewer species recorded in the field boundaries of all four sites in 1985 and 1986. Crop edge species numbers varied in individual fields with no obvious pattern. Decreases in 1986 in species numbers in the crop in the Integrated field were probably a result of herbicide applications in April. Changes in the number and diversity of species appeared to follow changes in width of the hedgebottom out to the crop. The width between the hedge and the planted crop was reduced in most sites in 1985 and markedly in 1986, following ploughing. Such a reduction in habitat size would be expected to affect species number and diversity.

TABLE 4

Attributes of the flora of four 50m sites divided into boundary and crop areas in July 1984, 1985 and 1986.

	Transect length (m)		No. species		Diversity (H')	
	Boundary	Crop	Boundary	Crop	Boundary	Crop
Full Insurance						
1984	1.07	2.93	16	4	1.945	1.117
1985	0.88	4.12	17	5	2.188	1.086
1986	0.60	4.40	15	7	2.044	0.921
Supervised (A)						
1984	1.95	2.05	38	10	2.976	1.559
1985	2.07	2.93	31	14	2.738	1.934
1986	1.26	3.74	29	12	2.669	1.456
Supervised (B)						
1984	1.21	2.79	13	6	1.760	0.840
1985	0.94	4.06	12	10	1.618	0.639
1986	0.36	4.64	6	6	1.477	1.293
Integrated						
1984	1.50	2.50	26	17	2.433	2.017
1985	1.05	3.95	21	16	2.485	1.959
1986	0.65	4.35	16	6	2.337	0.945

Manydown

On the Manydown Estate, the 6m of cereal crop adjacent to the boundary was either sprayed with herbicides as normal (FS), not sprayed in spring or summer (NSS) or left unsprayed during the season (NS). These experimental unsprayed headland treatments succesfully sought to increase the survival of partridge chicks by providing insect food items associated with dicotyledonous weeds (Rands 1985). The technique is being developed by CGRP and such margins are now known as Conservation Headlands. The treatments offer a measure of protection to the field boundary from herbicide contamination. Therefore, between 1984 and 1986, changes in the flora of a series of 50m lengths of hedgerow at Manydown were assessed. In the boundary the percentage cover of plant species was estimated by eye in 22 0.1 m2 quadrats along the 50m length. Assessments were made in May 1984 and in July in 1985 and 1986. Studies of the flora within the crop were also made and are reported elsewhere (Marshall 1986).

Six sites were studied for three years, while a further eight sites were investigated at least twice during the same period. The cropping of the fields and the headland treatments varied during the study. Changes in numbers of species per site were examined and the cover data used to calculate the Shannon-Weaver diversity index.

Manydown Results

The number of non-shrub plant species recorded in the boundaries are given in Table 5. In the first six fields, there was a trend for reduced herbicide use in the headland (NSS and NS treatments) to give similar or greater numbers of species in 1985 than in 1984. Fields which were sprayed up to the crop edge (FS treatments) tended to have fewer species in 1985. However, the trend was not confirmed by the data collected in 1986, which indicated considerable year-to-year variation.

TABLE 5

Numbers of non-shrub plant species in field boundaries on the Manydown Estate, 1984-1986, with crops and headland treatments.

Field	1984			1985			1986		
	Crop	Head.	Species No.	Crop	Head.	Species No.	Crop	Head.	Species No.
Hatchcroft	WW	NSS	13	WW	NS	22	SB	NSS	16
Pack Lane	WW	NSS	16	WW	FS	14	SB	NSS	18
Moores	WW	FS	20	SB	NS	17	SB	NSS	17
Lonely Meadow	SB	NSS	19	SB	NS	23	SB	NS	26
Farm Close	SB	FS	21	SB	FS	14	Peas		22
Great Woods E	SB	FS	25	SB	FS	22	Peas		22
Big Field	WW	NSS	18	SB	NSS	-	Peas		21
Scrapps Hill S	WW	FS	23	WW	FS	-	SB	NSS	31
Scrapps Hill N	WW	FS	17	WW	FS	-	SB	NSS	26
Teddys	SB	NSS	15	SN	NSS	-	Grass		17
Mothers East	SB	FS	13				Rape		21
Hansfords	WW	FS	-	WW	NSS	20	SB	FS	22
Rooksdown	WB	FS	-	WB	FS	20	WB	FS	21
Battledown S	WW	FS	-	SB	NS	32	SB	FS	32

(WW=Winter wheat; SB=Spring barley; WB=Winter barley. FS=full spray; NSS=no spring or summer sprays; NS=no sprays during the season.)

The mean percentage cover of species in the boundary were used to calculate the Shannon-Weaver diversity index (Table 6). In terms of species diversity, changes in the boundary floras at Manydown did not indicate any direct effect of reduced herbicide input from field applications.

TABLE 6

The Shannon-Weaver diversity index (H') for six boundaries and their headland treatments, Manydown 1984-1986.

Field	1984		1985		1986	
	H'	Headland	H'	Headland	H'	Headland
Hatchcroft	1.500	NSS	2.413	NS	2.169	NSS
Pack Lane	1.895	NSS	2.155	FS	1.906	NSS
Moores	2.432	FS	2.431	NS	2.253	NSS
Lonely Meadow	2.614	NSS	2.284	NS	2.040	NS
Farm Close	1.938	FS	1.591	FS	1.599	-
Great Woods E	2.224	FS	2.009	FS	2.503	-

(FS=full spray; NSS=no spring or summer sprays; NS=no sprays during the season.)

Discussion

The data collected at Boxworth, where different herbicide regimes within the entire field were applied, and at Manydown, where different headland treatments were practiced, did not indicate botanical changes which could be correlated with herbicide use. Both spatial and temporal variation without consistent trends were shown in the numbers of species found and in measures of species diversity. It is tempting to conclude, therefore, that applications of herbicides to crops do not affect field boundary floras. This might be the case, but further considerations are required. For example, the initial composition of the field boundaries may have been so affected by previous herbicide practice that botanical change was limited by lack of propagules.

The measures of botanical change that have been examined in the two studies are essentially at the community level. Broad changes in botanical diversity have been sought, while changes in individual species have not been considered. At the species level, temporal and spatial variation is likely to be large, and difficult to follow, on this scale of field monitoring. Diversity indices summarise considerable amounts of data but have been widely used in ecology, including pollution studies (Zand 1976), to describe differences in communities in time and space. The present data show changes, but these appear unrelated to herbicide use. It is likely that on the farms examined, herbicide drift is not of major significance. Under normal spraying conditions, spray drift is minimal beyond 10m and the amounts of active ingredient reaching field boundaries is thought to be small. The Boxworth data certainly indicate that factors other than herbicides were important in botanical change in the field boundary. In particular, there was some evidence that disturbance by close cultivations before the crop was drilled was the major factor affecting the flora. Other forms of disturbance, for example fertiliser contamination and burning, may also affect boundary floras. There is little information on the relative contribution of these influences or of any interaction between them. While the present studies shed some light on the role of herbicides in field boundaries, clearer insight can only be gained from further detailed and controlled experimentation.

THE SUSCEPTIBILITES OF HEDGEROW PLANTS TO HERBICIDES

While some information on the susceptibility of plant species to herbicides is available in the technical literature for commercial products, it is impractical for manufacturers to test a wide range of non-target species. Initial investigations to extend the information on hedgerow plant susceptibilities were described by Marshall & Birnie (1985). Further studies on pot-grown hedgerow plants have now been made. Pot studies may not reflect the results of field applications of herbicides. In the field, soil-acting herbicides are likely to be less effective than in pots, while low doses of some herbicides might affect the competitive ability of some species, resulting in greater changes of botanical composition than indicated in pot experiments. Nevertheless, useful relative information is obtained, some of which may indicate experimental approaches to the direct manipulation of boundary floras.

Forty-two ground flora species were established in 1 litre pots during the autumn of 1985 and were treated during the spring of 1986 (glyphosate in July). Plant vigour was scored on a ten point scale (0=dead, 9=unaffected. Marshall & Birnie 1985). Pots were sprayed with the recommended field rate of a series of herbicides and three plant growth regulators, using a laboratory pot-sprayer delivering 300 l/ha. Not all species were treated with each compound; certain species had already been tested with some herbicides and insufficient material was available for other species. A summary of the numbers of species tested and the number with significantly lower vigour scores to control plants at six or 15 weeks is presented here.

Results and Discussion

The results of the pot experiments conducted during 1986 on the hedgerow plant species are summarised in Table 7. The chemicals used are grouped according to their recommendations for use, and the numbers of grass and dicotyledonous species tested and significantly different to controls are compared.

TABLE 7

Numbers of broad-leaved and grass species tested with different herbicides and plant growth regulators and numbers significnatly reduced in vigour at six or fifteen weeks after treatment.

Chemical	Rate applied (kg (a.i.)/ha)	Broad-leaved species Tested	Broad-leaved species Affected	Grass species Tested	Grass species Affected
mecoprop	2.40	14	8	0	-
2,4-D	0.70	28	12	10	0
fluroxypyr	0.20	27	19	10	0
ioxynil+bromoxynil	0.76	15	4	0	-
clopyralid	0.20	15	4	0	-
diclofop-methyl	1.14	20	2	0	-
flamprop-isopropyl	0.60	27	3	0	-
difenzoquat	1.00	26	4	10	0
isoproturon	2.02	19	2	0	-
chlorsulfuron	0.015	22	9	0	-
metsulfuron-methyl	0.006	28	16	10	0
methabenzthiazuron	1.60	26	6	10	0
ethofumesate	2.00	30	12	0	-
glyphosate	1.40	25	20	10	10
mefluidide	1.60*	29	9	0	-
paclobutrazol	1.00	28	9	10	0
chlormequat	0.91	25	1	10	0

*=Four times recommended rate.

Of the broad-leaved weed herbicides examined, mecoprop, 2,4-D and fluroxypyr significantly affected a large proportion of species tested. Fluroxypyr was particularly active, reducing the vigour of 70% of the dicotyledonous species examined, while grasses were unaffected. Grass herbicides generally had few effects on dicotyledonous species. The soil-acting herbicides, such as isoproturon, had varied effects with the sulfonyl urea compounds, chlorsulfuron and metsulfuron-methyl, showing the widest spectrum of activity. Glyphosate, as expected, affected the most dicotyledonous and grass species, following application in July. Among the growth regulators, chlormequat affected only one species, while the grass retardants, mefluidide and paclobutrazol affected 30% of the dicotyledonous species. The effects of mefluidide may have been overestimated as the rate applied was four times that recommended. Apart from glyphosate treatments, no compound adversely affected the grass species examined.

These investigations demonstrated that many non-target species found in field boundaries were susceptible to field rates of commonly used herbicides. Certain compounds, notably mecoprop, fluroxypyr, metsulfuron-methyl and glyphosate, were capable of affecting a wide range of species. If unusual spraying conditions pertain, where considerable amounts of active material of such compounds contaminate the hedge, then severe effects on species composition might be expected.

CONCLUSIONS

Examinations of the relative susceptibility of plant species have shown that many non-target plants may be affected by field rates of some chemicals. Risk of damage to hedgerow floras is greatest from contamination by broad spectrum compounds, such as mecoprop, fluroxypyr, metsulfuron-methyl and glyphosate. The amounts of active ingredient actually deposited in the field boundary is almost infinitely variable, ranging from full field rate with accidental or deliberate over-spraying to nothing under optimum spraying conditions. Field examinations on two farms where different herbicide regimes were practiced, and hence different opportunities for contamination existed, have indicated that herbicides probably do not play a major role in changes in the existing flora.

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WEED CONTROL AT FIELD MARGINS: EXPERIMENTAL TECHNIQUES AND PROBLEMS

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ABSTRACT

Hedgerows damaged by agrochemicals, fertilisers or fire are rapidly colonised by undesirable annual grass and broadleaved weeds. Selective herbicides used to control these species and allow regeneration of the perennial flora showed some advantages in the short term but, after 5 years there was still a need for annual herbicide applications to maintain beneficial effects.

The use of herbicides on hedge bottoms and ditch sides is unacceptable for environmental reasons. Alternative weed control techniques are being explored such as repeated topping of the panicles of annual grasses, and the use of sterile boundary strips. Experimental techniques and associated difficulties are discussed.

INTRODUCTION

A small number of species occurring in the hedge-bottom flora also appear in the crop headland. Typical of these are *Elymus repens* (common couch), *Alopecurus myosuroides* (black-grass), *Poa trivialis* (rough meadow-grass), *Bromus sterilis* (barren brome), *Galium aparine* (cleavers), *Convolvulus arvensis* (field bindweed), *Fallopia convolvulus* (black-bindweed), *Cirsium arvense* (creeping thistle) and *Veronica persica* (common field-speedwell) (Marshall & Smith 1987, Roebuck 1987). Some of these annual species readily colonise cultivated ground and are serious competitors in arable crops. Consequently, the hedgerow habitat can be an important source of weed seeds.

A recent spot survey indicated that 39% of farmers who were questioned used herbicides to control potential crop weeds in their field boundaries, and more than half of these farmers used glyphosate (Greaves & Marshall 1987). Deliberate attempts to control hedge-bottom arable weeds by spraying with desiccant or systemic herbicides have led to greater problems from the prolifically seeding annuals such as barren brome and cleavers, which establish and propagate in the bare ground left after spraying.

Regeneration of the hedge-bottom flora in such situations by natural spread of surviving perennials is very slow in the face of competition from the aggressive annuals. Selective control of these annuals could perhaps hasten the repair of hedge bottoms and ditch sides. This was attempted by using herbicides varying in selectivity against annual and perennial grass and broadleaved species on a damaged hedgerow in Buckinghamshire (Experiment 1).

In view of the adverse environmental implications of herbicide use in hedge bottoms and ditch sides a second experiment was initiated. This was designed to evaluate the use of boundary strips to control field-margin weeds and prevent their spread into the adjacent crop, whilst at the same time offering a degree of protection to the hedgerow from fertiliser and pesticide spray drift.

EXPERIMENT 1

Materials and methods

A section of hedgerow bottom and adjacent ditch side near Stoke Mandeville, Buckinghamshire, which had been sprayed with glyphosate was selected as it contained a high proportion of *B. sterilis* and *G. aparine*. Plots of 20 m length were randomised twice down each side, the plot width being 1 metre at the hedge bottom and 2 metres at the ditch side. A barrier strip of one sprayer nozzle width (0.3m) of propyzamide was used between the plots and the crop edge to keep this area weed free.

Treatments were selected for activity against annual grasses and broadleaved weeds and also selectivity for perennial species.

asulam sodium	2.0 kg/ha a.i.	(5.0 l/ha Asulox)
endothal sodium	0.8 kg/ha a.i.	(4.0 l/ha Herbon Penout + wetter)
ethofumesate	1.0 kg/ha a.i.	(5.0 l/ha Nortron)
ethofumesate	2.0 kg/ha a.i.	(10.0 l/ha Nortron)

Herbicides were applied annually during November 1982 to 1986 by knapsack or Oxford Precision Sprayer in 225 l/ha at 2.5 bar using 8002 Spraying Systems T jets.

Results

Species were recorded on a per centage ground cover basis using 0.5 m^2 quadrats. Interim results for dominant species are shown in Table 1

TABLE 1

Percentage ground cover of weed species in field boundaries after two treatment years (Stoke Mandeville, November 1984).

Treatment	*Bromus sterilis*	*Elymus repens*	*Galium aparine*
Ditch side			
Nil	87	0	11
asulam	88	3	9
endothal sodium	68	13	18
ethofumesate (1.0 kg)	72	15	13
ethofumesate (2.0 kg)	82	8	10
Hedge bottom			
Nil	74	10	16
asulam	50	24	26
endothal sodium	55	31	14
ethofumesate (1.0 kg)	52	27	21
ethofumesate (2.0 kg)	19	44	37

After two years of treatment there was a small reduction of *B. sterilis* on the ditch side, and an increase in *E. repens*. Control of *B. sterilis* was better in the hedge bottom, but there were more cleavers which were not controlled by herbicides active against this weed (e.g. ethofumesate) (Table 1).

After five years the two habitats showed increases in useful hedgerow species such as *E. repens*, *P. trivialis*, *Lamium album* (white dead-nettle), Stachys sylvatica (hedge woundwort), Alliaria petiolata (garlic mustard), Anthriscus sylvestris (cow parsley), Urtica dioica (common nettle) and Glechoma hederacea (ground ivy) (Appendix I). the area under G. aparine showed little change over the years and there was still a higher proportion of B. sterilis and G. aparine in the hedge-bottom flora compared to the ditch side (Table 2).

TABLE 2

Percentage ground cover of weed species in field boundaries after five treatment years (Stoke Mandeville, February 1987).

Treatment	Bromus sterilis	Elymus repens	Galium aparine	Lamium album	Anthriscus sylvestris	Bare ground
Ditch side						
Nil	31	29	4	4	1	31
asulam	29	34	2	14	0	21
endothal sodium	25	40	5	3	0	27
ethofumesate (1.0 kg)	3	50	3	6	0	38
ethofumesate (2.0 kg)	22	26	17	13	1	21
Hedge bottom						
Nil	29	7	10	8	2	44
asulam	45	0	25.5	1	5.5	23
endothal sodium	27.5	20	38.5	4.25	0	9.75
ethofumesate (1.0 kg)	56	0	13.5	13.5	1.2	15.75
ethofumesate (2.0 kg)	22.5	36.5	20.5	4.75	0	15.75

By this stage the herbicides were no longer helping in the recolonisation of the changed areas because seed return of B. sterilis was not sufficiently well controlled.

EXPERIMENT 2

Materials and methods

A single site was selected on calcareous silty loam near Newbury, Berkshire which had a history of high headland weed populations. There were four experimental treatments.

Untreated: crop directly adjacent to hedge bottom
0.3 m wide boundary strip by atrazine (2.8 kg ai/ha)
1.8 m wide boundary strip by atrazine (2.8 kg ai/ha)
1.8 m wide boundary strip by rotary cultivation

The plots were established in the normally cropped area by destruction of the growing cereal during spring 1986 and re-established in the same area by a similar technique the following season. Atrazine was applied on 4 February and 9 December 1986 using an Oxford Precision Sprayer in 225 l/ha water at 2.5 bar and 8002 Spraying Systems T jets. Rotary cultivation was carried out on 14 May 1986 and 21 May 1987. Plots size was 25 m by 8 m; the long axis being parallel to the field edge. An

8 m by 8 m weed-free buffer area was maintained between plots to prevent cross contamination with weed seeds during cultivations and harvesting. No overall herbicide applications have yet been made to the trial area since its inception.

Weed populations were assessed in 0.25 m² quadrats at 1, 2, 3, 4, 6 and 8 m from the field edge along five transect lines per plot which had been permanently marked. Ground cover was assessed on the narrow strip of semi-natural vegetation at the origin of each transect line.

Results

Grass weed populations were reasonably uniform throughout the considerable length of the trial prior to treatment, although the distribution of broadleaved weed tended to be rather patchy. The population of all species was higher adjacent to the field boundary and declined with increasing distance into the cropped area (Fig. 1).

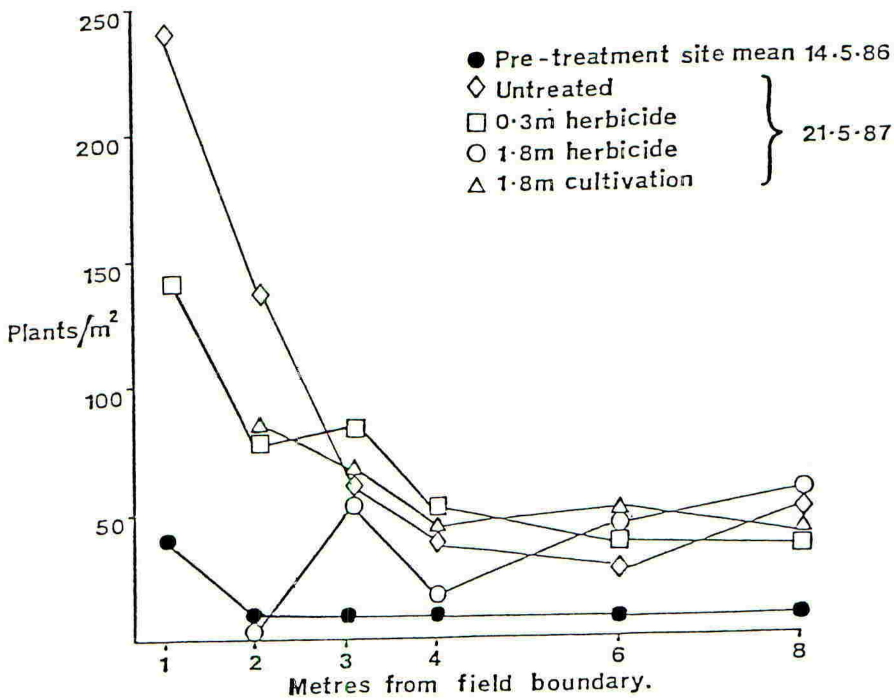

Fig. 1. Grass weed population and distribution across headlands pre- and post-treatment.

At the end of the first year, grass weed populations had risen across the entire width of the headland but the increase was greatest adjacent to the field boundary and in the untreated plots. The population of broadleaved weeds also increased overall after one year but was greatest at a point roughly 3 metres from the field boundary (Fig. 2).

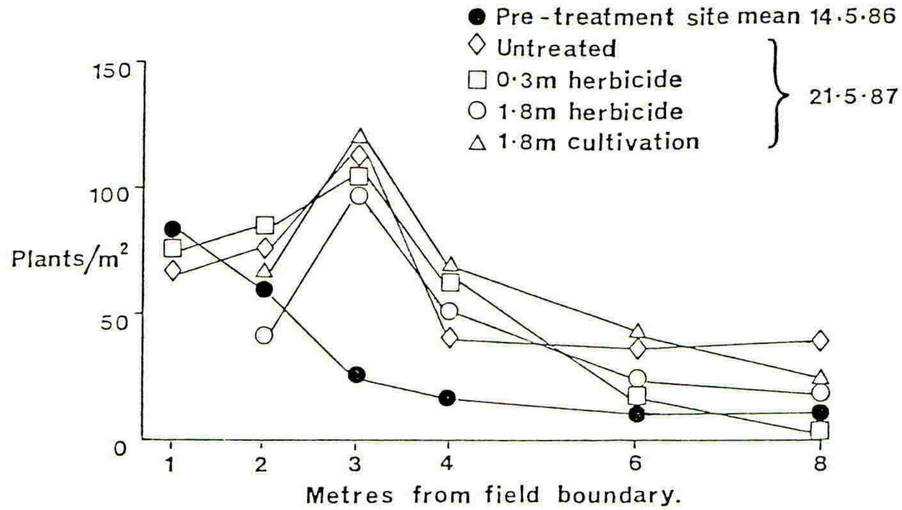

Fig. 2. Broadleaved weed population and distribution across headlands pre- and post- treatment.

Both the 1.8 m wide atrazine treated and cultivated strips remained relatively free of grass weeds until harvest by which time small broadleaved weeds were apparent. The 0.3 m atrazine strip also remained weed free, but a number of large plants of B. sterilis and G. aparine had lodged or spread over the bare soil having grown from the adjacent untreated areas.

GENERAL DISCUSSION

Experiment 1 investigated the effects of selective herbicide use on a previously damaged field margin flora. The results were encouraging and suggested that some degree of beneficial manipulation was possible using selective compounds. Unfortunately, the assessments made did not quantify the effects on all species present, but merely some indicator species. Data are available on the activity of certain broad-spectrum herbicides against a wide range of field margin species (Birnie 1984, Marshall & Birnie 1985), but not for the selective materials used in this study. Field boundaries can provide important wildlife habitats (Pollard et al 1974, Way 1972) for a variety of reasons (Hooper, 1987) and the use of any herbicide or fertiliser in these areas is becoming increasingly unacceptable. In view of this and the small likelihood of additional data likely to be forthcoming, Experiment 1 has been discontinued in its original format. The site will be used to evaluate regular mechanical topping as a management technique to control annual grass weeds.

Experiment 2 was designed to evaluate sterile boundary strips to allow natural regeneration of hedge bottoms, and at the same time protect the cropped area from weed ingress from the field margin. Some aspects of this study were based on preliminary unpublished experiments carried out by staff at Long Ashton Research Station. This technique has been frequently practiced on commercial farms, but the agronomic and environmental effects are poorly understood. Four replicates have been included to allow more precise analysis of the data than was possible with Experiment 1 which was replicated only twice, but in practice the requirement for extra plot area made selection of a reasonably uniform site very difficult. The use of facilities on a commercial farm reduced the number of treatment options; for example a boundary strip sown with grass was not included mainly for this reason, although this has been possible on further sites initiated recently on ADAS Experimental Husbandry Farms.

The management of weeds on the headlands as a whole has also proved difficult because of the compromise needed between having sufficient weeds to measure treatment differences accurately, but also to avoid excessively high populations untypical of commercial farming. It is expected that Experiment 2 will need to be continued for at least 5 years to allow subtle treatment differences to develop, and a multi-disciplinary team will be required to assess changes of both agronomic and environmental importance fully.

Annual labour inputs have been considerable for this type of experiment and for Experiment 1 have been estimated at 11 man days and at 40 man days for Experiment 2. The costs and difficulties involved need to be considered fully before an apparently simple series of experimental treatments can be initiated.

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APPENDIX I

EXPERIMENT 1

Per cent ground cover of hedgerow species after five treatment years (Stoke Mandeville, July 1987)

Treatment	Bromus sterilis	Elymus repens	Arrenatherum elatius	Alopecurus myosuroides	Galium aparine	Anthriscus sylvestris	Alliaria petiolata
Nil	18	9	1	1	19	35	2
asulam	8	16	6	0	8	16	0
endothal	29	20	2	3	1	23	0
ethofumesate (1.0 kg)	11	15	6	3	9	9	2
ethofumesate (2.0 kg)	10	14	1	1	10	20	4

Treatment	Lamium album	Urtica dioica	Convolvulus arvensis	Aethusa cynapium	Stachys sylvactica	Glechoma hederacea
Nil	2	8	1	0	1	0
asulam	9	10	3	1	9	1
endothal	7	7	2	2	0	1
ethofumesate (1.0 kg)	6	12	1	1	2	10
ethofumesate (2.0 kg)	1	12	1	1	16	6