SESSION 7B

GRASSLAND AND OTHER FORAGE OR FODDER CROPS

SESSION 7B

CHAIRMAN PROFESSOR C. R. W. SPEDDING

SESSION ORGANISER MR R. WHITEHEAD

INVITED PAPERS 7B-1 to 7B-7

AN AGRO-ECONOMIC REVIEW OF GRASS AND OTHER FORAGE CROPS

C. J. DOYLE

Animal and Grassland Research Institute, Hurley, UK

ABSTRACT

The comparative economics of growing and utilizing a variety of forage crops are examined. Crops like fodder beet, grass, maize, swedes, kale and lucerne are shown to be as profitable as oilseed rape and cereals. Also investigated are the economics of controlling weeds in forage crops. It is estimated that in general the yield response to weed control should be in the range of 0.5 to 1.0 t d.m./ha if use of herbicides is to be justified economically. Since observed responses to herbicides are frequently less than this, blanket recommendations for weed control in forage crops are not possible. Instead the key to cost-effective use of herbicides is the derivation of threshold levels of weed infestation, below which it is uneconomic to use chemical sprays.

INTRODUCTION

With tightening financial margins, livestock producers need to explore ways of containing costs. For the majority of milk and beef producers, one way of achieving cost savings is through relying on grass and other forage crops to satisfy an increasing proportion of animal feed requirements. To realise the economic advantage from feeding these crops high yields must be obtained. Among other things this involves limiting the losses caused by weed infestation.

This paper opens with a brief examination of the comparative economics of growing and utilizing a variety of forage crops. The crops considered include grass (grazed, ensiled), cereal forages (rye, whole-crop wheat, maize), legumes (white clover, red clover, lucerne, forage peas), brassicas (kale, rape) and root crops (swedes, fodder beet). This is followed by a discussion of the economics of controlling weeds in forage crops.

COMPARATIVE ECONOMICS OF SELECTED FORAGE CROPS

Yields and production costs

In comparison to the area under grass, that under other forage crops is insignificant, totalling no more than 250 000 ha (Ministry of Agriculture, Fisheries and Food 1983a). However, potentially many of the alternative forages offer certain attractions to livestock producers as break and nurse crops and a small, but increasing, area may be set aside to them in the future.

The potential dry-matter yields and energy and protein contents of grass and other forages, as recorded by the National Institute of Agricultural Botany (1984a, 1984b, 1985), are shown in Table 1. The energy content is expressed in megajoules (MJ) of metabolisable energy per kilogram of dry-matter, while protein content is measured in grams of digestible crude protein (DCP) per kilogram of dry-matter (see Ministry of Agriculture, Fisheries and Food (1975) for a definition of these measures). Where crops are commonly fed as silage or hay, then the figures in Table 1 relate to the utilisable yield, after allowance for dry-matter, energy and protein losses in conservation.

TABLE 1

Utilisable dry-matter, metabolisable energy and digestible crude protein yields for various forages after allowance for losses in conservation

Crop	Form as fed	Dry-matter yield (t d.m./ha)	Metabolisable energy (MJ/kg d.m.)	Digestible crude protein (g/kg d.m.)
Grass	grazed	10.0	11.2	130
Grass	ensiled	10.0	10.7	91
Rye/triticale	grazed	5.0	9.5	88
Whole-crop wheat	ensiled	10.0	10.2	50
Maize	ensiled	11.3	10.8	50
Grass/ white clover	grazed	8.0	11.4	130
Red clover	ensiled	9.4	10.0	128
Lucerne	ensiled	12.1	9.5	113
Forage peas/ barley	ensiled	7.2	11.5	77
Kale	grazed	5.9	10.9	122
Rape	grazed	3.5	11.2	144
Swedes	in clamp	6.3	13.9	64
Fodder beet	in clamp	13.5	12.5	50

Estimated costs of production per hectare at 1985 prices for each of the forages in Table 1 are shown in Table 2. Production costs have been divided into those associated with 'cultivation' and those relating to 'harvesting'. The former include the costs of seed, fertilizer, cultivation and rent, while the latter comprise the costs of additives, harvesting and, where appropriate, storage. As production costs have been calculated for a presumed weed-free site, the costs of any weed control have been excluded. The charges for operations, such as ploughing, mowing and picking up the crop, have been based on quotes supplied by contractors (Farmers Weekly 1984). Costs of seed, fertilizer and additives have been taken from Doyle (1984). Finally, storage costs for 'ensiled' crops have been based on using a sleeper-walled silo at £20/t d.m., while those for crops 'in clamp' have been based on using straw bales at £10/t d.m.

TABLE 2

Comparative costs per hectare for the cultivation and harvesting of various forage crops

Crop	Cultivation costs (£/ha)	Harvesting costs (£/ha)	Total costs	
			(£/ha)	(£/t d.m.)
Grazed grass	302	0	302	30.2
Grass silage	325	419	744	74.4
Rye/triticale	287	0	287	57.4
Wheat silage	261	464	725	72.5
Maize silage	301	324	625	55.3
Grass/ white clover	156	0	156	19.5
Red clover silage	352	395	747	79.5
Lucerne silage	284	534	818	67.6
Pea/barley silage	257	297	554	76.9
Kale	254	0	254	43.0
Rape	225	0	225	64.4
Swedes	271	193	464	73.6
Fodder beet	268	265	533	39.5

Estimated values and net margins

However, the production costs of a crop are no indication of its market value. For the economic benefits of measures such as weed control to be evaluated, an estimate of the crop's value is required. However, apart from small quantities of dried lucerne and grass hay, little in the way of forage crops is sold off the farm, so that these crops do not have quotable market prices. In consequence, the value of grass and other forage crops must be estimated indirectly from their contribution to livestock production. Any values so derived will depend on the livestock activity being considered and the specific use to which the forage is put (Doyle 1985). Notwithstanding this, estimated values have been derived for each of the crops in Table 1 by finding the maximum price which a livestock producer would be willing to pay for the forage. To do this it has been assumed that the alternative to growing and feeding a particular forage crop is to rely entirely on purchased feeds, namely grass hay and concentrates, to meet animal requirements. Least-cost rations have been formulated for specific animals. The price for a particular forage, above which purchased hay would displace it from the diet, has then been found. This price has been taken to be the maximum price which the forage would command, if it had been traded.

For each forage the maximum price at which it would be incorporated in the diet has been calculated, firstly for a dairy cow yielding 25 kg/day of milk and secondly, for a beef steer weighing 350 kg and gaining 0.7 kg/day. Beside the particular forage, the feeds on offer were considered to be good quality hay, barley and soya bean meal, which could be purchased at prices of £72, £128 and £148 per t d.m. respectively. The metabolisable energy and digestible crude protein contents of the hay were taken to be 9.0 MJ/kg d.m. and 58 g/kg d.m. respectively. The corresponding figures for barley were 12.9 MJ/kg d.m. and 82 g/kg d.m., while those for soyabean meal were 12.3 MJ/kg d.m. and 453 g/kg d.m. (Ministry of Agriculture, Fisheries and Food 1975). Details on the assumptions about animal requirements for energy and protein and the limits on dry-matter intake can be found in Doyle (1984). For each forage the mean of the prices derived from the ration formulations for the dairy cow and the beef steer has been calculated and this figure has been taken to be a representative market value for the crop. The resultant imputed values for the various forages are shown in Table 3.

Taking the crop values in Table 3 it is possible to derive notional 'gross' or 'net margins' per hectare for each of the forage crops. In so far as there are significant differences in the fixed costs associated with each of the crops, the 'net margin' probably provides a more representative comparison. This figure is defined as the receipts from the sale of the crop less expenditure on seed, fertilizer, sprays, labour, machinery, rent and general overheads. As such, the 'net margin' is broadly consistent with the value of the crop expressed per hectare, less the costs per hectare reported in Table 2. The resultant 'net margins' per hectare are given in Table 3.

TABLE 3

Estimated market values for various forages and the implied net margin per hectare based on yields and production costs given in Tables 1 and 2

Crop	Value (£/t d.m.)	Net margin (£/ha)	Crop	Value (£/t d.m.)	Net margin (£/ha)
Fodder beet	112.8	990	Pea/barley	95.3	132
Grazed grass	92.0	618	Lucerne silage	78.0	126
Grass/clover	96.3	614	Rape	99.0	122
Maize silage	94.0	437	Wheat silage	84.5	120
Swedes	125.5	327	Rye/triticale	77.5	101
Kale	96.5	315	Red clover silage	82.8	31
Grass silage	89.3	149			

The comparable net margins per hectare for oilseed rape, sugar beet, wheat and barley are £500, £439, £250 and £130 respectively (Nix 1984). While the figures in Table 3 should be treated with caution, it would appear that forage crops such as fodder beet, grazed grass, grass/clover and maize silage offer net margins at least comparable to those from oilseed rape and sugar beet. Swedes, kale, grass silage, pea and lucerne silage exhibit margins similar to those from cereal crops. Only in the case of red clover is the net margin comparatively low.

BENEFITS OF WEED CONTROL IN FORAGE CROPS

Feasible expenditure on weed control

Compared to arable crops, it is less easy to quantify the costs resulting from a failure to control weeds. First, although the potential losses in dry-matter yield can be assessed for forage crops, the extent to which these losses are translated into losses in animal output is less easily measured. The latter will depend not only on the reduction in crop yield, but also on the proportion of the crop which is effectively utilised (Doyle 1985). Second, species commonly considered 'weeds' in grass and other forage crops may not differ agronomically or botanically in any substantial degree from the crop itself (Doyle 1985). Thus, although the presence of rough meadow-grass (*Poa trivialis*) in a predominantly ryegrass (*Lolium perenne*) sward may depress the yield of ryegrass, the meadow-grass itself has a feeding value. Even weeds like broad-leaved dock (*Rumex obtusifolius*) have been shown to have a feed value as far as livestock are concerned, which partially compensates for its depressive effect on the forage crop yield (Courtney & Johnston 1978). Possibly, only in the case of poisonous weeds, such as ragwort (Senecio jacobea), is there a clear nutritional disadvantage. Third, for perennial crops, like grass, lucerne and red clover, there is the added problem that weed control measures in one year will have effects in subsequent years. However, few experiments have documented the impact of weed control measures beyond the first two years.

Faced with these difficulties, coupled with limited information on the relationship between weed density and yield losses for most forage crops (Doyle 1985), it is difficult to draw up specific weed control recommendations. However, it is arguably possible to draw up some general guidelines. In particular, for each forage crop an estimate can be made of the expenditure on weed control which a farmer should be willing to make in order to prevent a given yield reduction arising from weed infestation. For various forage crops the projected reductions in net margin per hectare caused by 1 t d.m. decrease in crop yield per hectare are shown in Table 4. The reductions in margin have been derived from the production costs and imputed crop values given in Tables 2 and 3, by assuming that the costs of 'cultivation' in Table 2 are independent of yield, while those for 'harvesting' are proportional to yield. Thus, the decrease in net margin for a tonne d.m. reduction in yield is simply the imputed value per tonne d.m. of the crop less the 'harvesting' costs per tonne d.m.

TABLE 4

Reduction in net margin per hectare arising from a yield decrease of 1 t d.m./ha for various forage crops

Crop	Reduction in margin (£/ha)	Crop	Reduction in margin (£/ha)
Rape	99.0	Maize silage	65.3
Kale	96.5	Pea/barley silage	54.1
Grass/clover	96.3	Grass silage	47.4
Swedes	94.8	Red clover silage	40.8
Fodder beet	93.2	Wheat silage	38.1
Grazed grass	92.0	Lucerne silage	33.9
Rye/triticale	77.5		

Assuming that the weeds responsible for the reduction in crop yield have no economic value, then the decrease in net margin given in Table 4 represents the maximum expenditure per hectare on weed control, which is economically feasible, where the anticipated improvement in resultant crop yield is 1 t d.m./ha. For larger or smaller expected yield improvements, the maximum feasible expenditure is increased or decreased proportionately. In the case of perennial crops like grass, red clover and lucerne, in estimating the likely yield improvements from weed control account should be taken of the benefits not only in the immediate year, but also in subsequent years. Examining Table 4 shows that for nearly half the forage crops considered expenditure on weed control could exceed £90 for every extra tonne d.m. realised.

Economics of weed control

Whether it is economic to use a particular herbicide to control weeds will depend on both the cost of the herbicide (including application) and the expected yield improvement from using it. While the costs are easily quantified, it is very much more difficult to estimate the likely yield increase, since the response to any herbicide varies markedly between sites. In a trial conducted at 7 sites and involving the application of ethofumesote to newly sown grass swards to control chickweed (*Stellaria media*) and annual meadow-grass (*Poa annua*), Goldsworthy *et al*. (1980) found increases in grass yield ranging from 700 to 4000 kg d.m./ha. In the light of this, efforts have been confined to estimating the minimum anticipated increase in crop yield for herbicide use to be justified. Since it is impractical to consider all the herbicides used on forage crops, attention has been restricted to a few of the more commonly recommended ones.

For each herbicide and each forage crop the minimum yield increase required to justify spraying the crop has been calculated by comparing the cost of the herbicide with the loss in net margin given in Table 4 for a yield reduction of 1 t d.m./ha. The costs of herbicides have been based on the recommended application rates given by the Ministry of Agriculture, Fisheries and Food (1983b, 1984a, 1984b). Included in the cost of the herbicide is the cost of application, assessed at £9/ha (Farmers Weekly, 1984). The resultant minimum yield improvements required to justify spraying are shown in Tables 5, 6 and 7.

Examination of Tables 5 to 7 reveals that, for the less expensive herbicides, costing under £30/ha (excluding application charges), their use in general would be justified economically if a yield response of about 0.5 t d.m./ha could be achieved. For more expensive herbicides, like glyphosate and ethofumesate, the break-even yield response is closer to 1 t d.m./ha. These yield increases should perhaps be compared with observed responses to herbicides. A survey of experiments on grass and other forage crops reported in the Proceedings of the British Crop Protection Conference - Weeds from 1966 to 1982 indicated that in 43% of cases the measured response was under 0.5 t d.m./ha. In 32% of cases the response was between 0.5 and 1 t d.m./ha, and in the remaining 25% of cases it was greater than 1 t d.m./ha. This would suggest

TABLE 5

Minimum yield increase in response to the use of a specific herbicide required to justify economically its use on grass and forage legumes (kg d.m./ha)

Crop	Herbicide				
	Mecoprop	MCPB	Dinoseb amine	Paraquat	Ethofumesate
Grass for grazing	180	255	295	390	705
Grass for ensiling	285	500	575	760	1370
Grass/clover	NR	245	285	375	NR
Red clover	NR	580	670	880	NR
Lucerne	NR	NR	830	1060	NR

NR = not recommended in any circumstance

TABLE 6

Minimum yield increase in response to the use of a specific herbicide required to justify economically its use on fodder beet, swedes, kale and rape (kg d.m./ha)

Crop	Herbicide				
	Tri-allate	Paraquat	Dalapon-sodium	TCA	Diclofop-methyl
Fodder beet	305	385	400	400	485
Swedes	300	380	395	395	475
Kale	295	370	390	390	465
Rape	290	360	380	380	455

TABLE 7

Minimum yield increase in response to the use of a specific herbicide required to justify economically its use on cereal forages (kg d.m./ha)

Crop	Herbicide				
	MCPA	Mecoprop/ dicamba	Simazine	Difenzoquat	Glyphosate
Rye/triticale	205	290	580	695	840
Wheat for ensiling	410	590	1180	1420	1705
Maize for ensiling	240	345	690	825	995

that in a considerable number of instances the use of herbicides might not be economically justified. Accordingly, it is unlikely that blanket recommendations for the use of herbicides on forage crops can be made (Doyle 1985).

CONCLUSIONS

Since the use of herbicides on forage crops may only be justified economically in certain circumstances, there is a need to devise criteria which will indicate when herbicides can be used to financial advantage. Such criteria might include the time of sowing, weather conditions at sowing and critical levels of weed infestation. A survey of the literature on weed control in forage crops reveals that information of this type is scarce, especially with regard to critical levels of weed infestation. In general, experiments have primarily been concerned with establishing that weed control improves crop yields and only secondarily with relationship between the degree of weed infestation and the reduction in yield of the crop. To evaluate confidently the costs and benefits of weed control, more data are needed on the latter aspect.

REFERENCES

Courtney, A. D.; Johnston, R. T. (1978) A consideration of the contribution to production of _Rumex obtusifolius_ in a grazing system. _Proceedings 1978 British Crop Protection Conference - Weeds 3_, 823-831.

Doyle, C. J. (1984) An economic comparison of alternative forages. Paper presented to ADAS Open Agronomy Conference, Oxford, 17-19 December 1984.

Doyle, C. J. (1985) Weeds, pests and diseases in grassland - an economist's view. In: British Grassland Society Occasional Symposium No. 18 J. S. Brockman (Ed) (forthcoming).

Farmers Weekly (1984) Contractors. Farmers' Weekly Supplement, 21 December 1984.

Goldsworthy, J. A.; Duke, L. G.; Whitehead, R. (1980) Control of weed grasses and Stellaria media in grass with ethofumesate. Proceedings 1980 British Crop Protection Conference - Weeds 2, 483-488.

Ministry of Agriculture, Fisheries and Food (1975) Energy Allowances and Feeding Systems in Ruminants, London: HMSO.

Ministry of Agriculture, Fisheries and Food (1983a) Agricultural Statistics United Kingdom 1983, London: HMSO.

Ministry of Agriculture, Fisheries and Food (1983b) Weed Control in Grassland, Herbage Legumes and Grass Seed Crops 1983-84, Alnwick: MAFF (Publications).

Ministry of Agriculture, Fisheries and Food (1984a) Weed Control in Fodder roots, Kale and Fodder Rape 1984-85, Alnwick: MAFF (Publications).

Ministry of Agriculture, Fisheries and Food (1984b) Weed Control in Cereals. Spring and Summer 1984, Alnwick: MAFF (Publications).

Nix, J. S. (1984) Farm Management Pocketbook, 15th edn., Ashford: Wye College.

National Institute of Agricultural Botany (1984a) Recommended Varieties of Forage Maize 1984. Farmer's Leaflet No. 7, Cambridge: NIAB.

National Institute of Agricultural Botany (1984b) Recommended Varieties of Grasses 1983/84. Farmer's Leaflet No. 16, Cambridge: NIAB.

National Institute of Agricultural Botany (1985) Recommended Varieties of Fodder Crops 1985. Farmer's Leaflet No. 1, Cambridge: NIAB.

WEEDS IN NEWLY ESTABLISHED LEYS AND OTHER GRASSLAND

J.S.BROCKMAN

Seale-Hayne College, Newton Abbot, Devon, United Kingdom.

ABSTRACT

The recent BCPC/BGS Symposium at Nottingham University provided a forum for the collation of much useful information on weed problems and control in grassland. This paper summarises the work describing the major weeds of both newly sown and established grassland; the nutritional value of some major weeds; and aspects of cultural, chemical and biological control of weeds. Finally, the points to consider in estimating economic thresholds are mentioned, together with a summary of the Syndicate discussions that followed the presentation of Symposium papers and some personal observations on them.

INTRODUCTION

This paper is based on information presented at the joint BCPC/British Grassland Society Symposium "Weeds, Pests and Diseases of Grassland and Herbage Legumes", held at Nottingham University in April 1985. The paper sets out to summarise the more important and topical points raised at the Symposium on weed problems, using three main headings; current weed problems, methods of control, economic aspects of control.

In the opening paper to the Symposium, Professor Spedding stressed the importance of studying the whole system. Thus removal of weeds from grassland must benefit the whole system and this benefit must have financial, not just physical, advantages.

Often, a change of one aspect within a system will have effects on the whole system, for example

- a switch to spring reseeding might minimise chickweed problems
- omission of "conscience clover" can lead to cheaper and simpler herbicide programmes
- change from conventional to minimal reseeding cultivations will change the weed spectrum.

In setting up a weed control programme in grassland, the key elements to consider are the economics of the programme, together with its effectiveness in controlling target weeds and its lack of harmful effects on key plants, stock and the environment.

CURRENT WEED PROBLEMS

Much useful information was presented on the major weed problems found in newly-sown grassland and in established swards.

Weeds of newly-sown grassland

Haggar *et al* (1985) have summarised data from surveys of grass sown both after several years of arable cropping and where grass is established after previous grass. Table 1 shows the main species found, and indicates that Stellaria media and Poa annua are common in both situations.

TABLE 1
Main weed species found in newly sown grassland.

GRASS AFTER ARABLE	GRASS AFTER GRASS
Elymus repens	Spergula arvensis
Avena fatua	Chenopodium album
Alopecurus myosuroides	Capsella bursa-pastoris
Stellaria media	Stellaria media
Poa annua	Poa annua
Viola arvensis	
Galium aparine	

In a survey of 95 newly-sown fields, Haggar et al found S. media was a problem in 50% of fields and P. annua was a problem in 37%.

In the short term, weeds decrease the number of grass plants established and so restrict the yield and quality of the sward. In the longer term, the yield and persistence of the field can be affected, as grass tillering can be reduced. Haggar et al cite an autumn grass/clover reseed where the presence of 25 S. media plants m^{-2} halved the ground cover of ryegrass and virtually eliminated the white clover.

Weeds of established grass

Hopkins & Peel (1985) summarised information from a number of surveys, including the National Farm Study (NFS) of permanent grassland that included 502 farms. In all, the information reviewed covered 112,000ha of grassland, of which 5,000 in S.W. England was surveyed both in 1970/72 and 1983.

The main weed species and extent of infestation is given in Table 2. 'Infested' is taken as both well distributed over the field and either more than 5% of field affected or at least 1 plant $16m^{-2}$.

TABLE 2
Main weed species found in old grassland

	% fields infested
Rumex obtusifolius & R. crispus	10
Cirsium spp. (mainly C. arvense)	20
Ranunculus spp.	15
Senecio jacobaea	1
Juncus spp.	10

Rumex spp. are widely distributed and 40% of farmers in the NFS saw them as a problem. They are more of a problem where the soil is high in P (but low in K), where N rates are high, slurry is used and the field is often cut for silage. They are less of a problem in fields grazed by sheep, cut for hay and liable to flood.

Cirsium spp. are mainly a weed of older grassland, particularly where PK levels are good, little N is used and drainage is adequate. Low stocking rates, with long rest periods in late summer, favour thistles.

Ranunculus spp. are most frequent in old badly drained lowland swards, often associated with Agrostis/Festuca dominance, low N rates, cutting for hay and overgrazing in winter. Raising stocking rate by use of more N will decrease buttercups: the S.W. England survey showed a 50% decrease in buttercup infestation over 10 years as a result of a rise in N rate to over 200 kg ha^{-1}.

S.jacobaea is a problem of poorer grassland and its major importance is not its level of infestation, but its effect on animals (Forbes, 1985). The effect of this plant fed in silage at sub-lethal rates on animal production is unknown.

Less desirable grass species

There is much debate on the relative merits of unsown grass species. Table 3 is constructed on the basis of information presented by Dibb (1985).

TABLE 3
Major characteristics of unsown grass species

	In comparison with Lolium perenne d.m. yield	D-value	Acceptability to stock
USEFUL GRASSES			
Holcus lanatus	good	low	√
Agrostis spp	good at low N	low	√
	poor at high N	poor	
Festuca rubra	good at low N		√
P.trivialis &			
P.pratensis	good	low	√
Alopecurus pratensis	good	low	√
Cynosurus cristatus	moderate	low	√
UNDESIRABLE GRASSES			
Deschampsia caespitosa	worthless		
Brachypodium pinnatum	very unpalatable		
Holcus mollis	v-poor; dense clumps force out other grasses		
Hordeum murinum	very unpalatable; possibly injurious		
Bromus mollis	has some value in hay meadows		
Anthoxanthum odoratum	v. low yield and unpalatable		
Poa annua	prolific coloniser of bare ground; not very competitive; indicator of problems		

7B—2

Nutritional value of weeds

Some farmers feel a wide spectrum of plant species in a sward enhances the appeal and quality of the sward to animals. Barber (1985) presented an account of the nutritional value of common weeds of grassland. Table 4 presents a summary of the main results presented.

TABLE 4
Summary of the nutritional value of some common weeds

	crude protein value	ME	major mineral value
Lotus corniculatus (1)	**	*	Na
Rumex obtusifolius	*** (May)	**	P,Mg
	0 (July)	0	
Tussilago farfara	* (May)	0	Cu
	0 (July)	0	
Taraxacum officinale	*** (May)	**	Mg
	* (Aug)	*	
Plantago lanceolata	* (May)	**	
	0 (July)	0	
Epilobium augustifolium	** (June)	0	P,Mg Mn,Co
	0 (July)	0	
Rumex acetosa (2)	*** (May)	***	P Mn
	0 (July)	0	
Vicia cracca	*** (May)	**	P
	*** (July)	*	
Achillea millefolium	*	**	P Cu

Key	0	<13	<9
	*	13-15	9-9.6
	**	16-19	9.6-10.3
	***	>19	>10.3

(1) can contain cyanogenic glycoside
(2) can contain oxalic acid

In addition, it was found that *Urtica dioica* was very high in Ca and *Cirsium* spp. very high in Ca and P.

CONTROL OF GRASSLAND WEEDS

Farmers often see the need to use chemical control of weeds in newly sown leys as a failure, probably caused by insufficient attention to sound cultural techniques. Thus it is unlikely that grassland farmers will make prophylactic use of chemical methods of weed control, but on the other hand, decision to use chemical methods may be based on a 'pride' factor rather than economic considerations (Newcomb, 1985).

Control by management

Sowing date can have a marked influence on weeds, and the present swing to late summer sowing encourages the development of S. media. Such late sowing restricts the rapid development of competition from sown grass and has a major effect on clover. Cooper and Jackson (1985) studied the chemical control of S. media in summer reseeds - not only did chickweed seriously impair the development of sown species, but also, even in weed free conditions, clover survival was halved when sowing date moved from 9 August to 21 September.

In syndicate discussions, a desirable move to spring sowing (including more undersowing) was mentioned as a way to both improve clover survival and minimise weed problems.

Another cultural approach is to use higher seed rates to minimise weed competition. Parr (1985) reported experiments where increasing grass seed rate from 5 to 80 kg ha^{-1} gave a decrease in weed yield after 14 weeks from 38% down to 7% of total yield. Parr's work was in amenity grass, but he concluded that in agricultural practice, seed rates of 40-80 kg ha^{-1} could limit weed problems, if such rates are an economic method of control.

Chemical Control

With the growing trend to late summer sowings of grass/clover swards, Cooper and Jackson (1985) found no standard label recommendations for clover-safe herbicides. In a series of experiments, they found all herbicide treatments that controlled S. media (the most serious weed) had some harmful effect on clover. The most effective and least damaging mixtures were

- benazolin/2,4-DB/MCPA
- bentazone/MCPB/MCPA

Addition of cyanazine to the latter enhanced its effect on S. media control but had a dose-related deleterious effect on clover.

Courtney (1985) from N. Ireland, reported long-term work on Rumex control, where currently dicamba/mecoprop mixtures are being studied. He stated that erratic and unpredictable control is attributable mainly to varying aspects of weather.

Forbes (1985) stated that at least 20% of the grassland infected with S.jacobaea should be sprayed annually, just to contain the infestation at its present national level. 2,4-D and MCPA applications are effective if sprayed at rosette stage (as opposed to stem elongation stage). Autumn spraying minimises the need to keep stock out of the area but gives only one year's control, whereas spring treatment can give two year's control. Glyphosate and dicamba applied by rope-wick applicator can be effective in selective control at flowering stage.

Haggar et al (1985) found that troublesome broad-leaved weeds in all-grass leys can be controlled by mixtures containing MCPA, mecoprop, dichlorprop, bromoxynil/ioxynil, dicamba and linuron, although some varieties of perennial ryegrass can be affected by mecoprop. Effective weed control in the presence of clover is more difficult, as most 'clover-safe' herbicides used to control broad-leaved weeds have some harmful effect on clover. Indigenous grasses can be controlled by ethofumesate, methabenzthiazuron and metamitron, but all three chemicals are extremely damaging to clover.

Ethofumesate controls effectively annual grass species at ryegrass establishment, and also controls S. media, but not most dicotyledenous weeds. Whitehead (1985) reported that a mixture of ethofumesate with bromoxynil and ioxynil combined control of grass weeds with troublesome dicotyledenous weeds.

Prospects for biological control

Greaves (1985) outlined the two approaches to control.

1. The classical approach, in which a pathogen is introduced to a weed, with no further manipulation, e.g. Puccinia chondrillina rust to control rush skeleton weed in Australia.

2. The inundative approach, where indigenous weeds can be controlled with indigenous pathogens. Normally, these pathogens will not control the weed due to their low population, incomplete life cycle or inadequate dissemination. It is possible to take a virulent strain of pathogen specific to the weed and mass produce it, then give a massive inoculation to the target weeds. Such biological controls are termed 'mycoherbicides' and there are two successful preparations on the market in USA, 'Collego' and 'Devine'.

It is known that some herbicides lower plant resistance to disease, and there is a possibility of 'modified mycoherbicides', e.g. low dose herbicide combined with mycoherbicide.

In syndicate discussions, it was questioned whether mycoherbicides would be regarded as environmentally more acceptable than chemical herbicides.

ECONOMIC ASPECTS OF CONTROL

Doyle (1985) pointed out that there are four particular difficulties in evaluating the cost benefits of weed control in grassland.

1. There is no traded value in grass and legumes, so their value has to be imputed from their contribution to livestock production.

2. The conversion of forage into animal product depends on the skill of the farmer: if the conversion efficiency is low, forage may be comparatively worthless.

3. There is a big variation in physical response between grassland sites and the extent of the difference often straddles the range between economic and uneconomic response.

4. Evaluation of weed control is difficult as often a "weed" species may not be all that inferior to "sown" species unlike arable situations (e.g. Poa trivialis v Lolium perenne, compared with wild oats in barley).

Valuing increases in herbage production

Using 1984 values, the value of grass in the field is likely to range from 1.7-5.1 p kg^{-1} d.m., with a mean of 3.5p.

Expressed as a proportion of crop value, herbicides for grassland are 2-3 times more expensive than those for cereals, leading to the need for a proportionately larger response in grassland for economic benefit. Thus an experiment reported by Goldsworthy over 7 sites showed that £81 ha^{-1} spent on ethofumesate gave a mean yield benefit of 1900 kg ha^{-1} d.m. If grass was worth 3.5p, then a yield benefit of 2300 kg would be needed: benefit greater than this was found at only 2 of the 7 sites.

From the above, it follows that economic thresholds are both needed, and of limited value unless very specific circumstantial information is provided.

Not only are short-term cost benefits worthy of study, but also long-term effects are likely. Being a perennial crop, benefits can be extended over more than one season. For example, an experiment studying dock control with asulam found that control of docks at 20% ground cover gave only 40% of the eventual yield benefit in year 1 and 50% in years 2 + 3.

Doyle concluded that the problem of evaluating economic weed control in grassland is not so much conceptual as one arising from lack of data.

DISCUSSION AND CONCLUSIONS

Delegates were divided into 6 syndicates and each syndicate discussed their views on the major points arising from the Symposium, and any obvious gaps in the material presented. Table 5 summarises the points (each * indicates the subject was brought out by 1 syndicate).

TABLE 5
Major points arising from syndicate discussion

MAJOR POINTS ARISING	
Are legumes necessary in grassland?	******
Environmental aspects of chemical use	******
Good husbandry minimises chemical need	****
Data on economic thresholds needed	****
Switch to spring sowing will alleviate some problems	***
Developments in biological & integrated control	**
GAPS	
Data on economic thresholds	*****
Future funding of necessary R & D	****
Work is needed to link weed, pest and disease control	***
Improved communication to farmer	***

7B—2

My comments on the major points raised by the Syndicates are as follows:

Role of legumes

At the present time, an extremely small area of grassland contains sufficient clover for the legume to make a worthwhile contribution either to sward N supply or nutritional enhancement of the herbage. Yet most farmers include clover in their seeds mixtures and insist on using "clover-safe" herbicides, often at greater cost/ha. than those suitable for "grass-only" swards. For white clover to be pulling its weight in a grass/clover sward, at least 50% of the ground cover should be clover in the August period, when clover growth will be at its seasonal maximum.

Environmental issues

Most environmental points came from discussion of pest and disease control, rather than weed control. However, it was clear that delegates were well aware of the need for great care and consideration of environmental issues in all aspects of herbicide use.

Thresholds

There is a need for thresholds, both agronomic ones to indicate when crop performance will be impaired by weeds and economic ones to suggest justifiable costs for control. Not only does the value of grass and the degree of control vary from site to site, but also the grass crop itself can consist of a wide range of plant species, many of which have a useful nutritional value.

One way to tackle this diverse situation is to segment the problems of grassland, either on a "grassland type" or "problem weed" basis. For example, Doyle's studies on grassland reseeding and Courteny's work on *Rumex* spp.

I feel in many farm situations the 'pride factor' of Richard Newcomb will trigger control *before* a calculated economic threshold is reached.

Better management

Current weed problems are the result of current crop management practices: a change in crop management will lead to a change in weed problem. For example, if a farmer wishes to make better use of clover, he must bring forward his September sowing date, preferably to the spring. This move could lessen greatly the problem of *S. media*, a point worth remembering if more "clover safe" herbicides to control *S.media* are being developed.

Funding or R & D

In the present climate, this aspect weighed heavily on the minds of delegates.

Communication to the farmer

Farmer and adviser delegates, to the surprise of those from industry, were very critical of the present volume and type of manufacturers' literature aimed at the farmer. Assuming a weed problem is identified as justifying chemical control the selection of an appropriate product is a decision that must be made rapidly. The mass of general literature is not seen as helpful at this stage.

Delegates felt more interactive methods of communication are desirable, for example by use of Prestel.

REFERENCES

All references cited in this paper will be found in British Grassland Society Occasional Symposium No.18 (1985).
J.S. Brockman, (Ed). Weeds, Pests and Diseases of grassland and herbage legumes. Proceedings of a joint British Crop Protection Council/British Grassland Society Symposium, Nottingham.

THE COMBINED CONTROL OF ANNUAL GRASS AND BROAD-LEAVED WEEDS IN NEW LEYS

B. L. REA, J. MARSHALL

FBC Limited, Nottingham Road, Stapleford, Nottingham, NG9 8AJ.

ABSTRACT

Two years' trials work is described with a novel combination of ethofumesate, with bromoxynil and ioxynil esters (CR 16804) used post-emergence in newly sown leys. Data from 18 replicated trials are presented to show wide spectrum annual grass and broad-leaved weed control, and crop selectivity compared to standard treatments. In these trials a dose rate of 5 l/ha providing 1.0 kg ethofumesate, 0.25 kg bromoxynil and 0.125 kg ioxynil/ha controlled Poa annua and other annual weed grasses, Stellaria media, Matricaria spp., Veronica persica, Lamium purpureum and Capsella bursa-pastoris. Results from five yield trials in the first production year showed statistically significant increases in rye-grass dry matter following treatment after sowing in the autumn, underlining the importance of weed control during the establishment of new leys.

INTRODUCTION

The development of ethofumesate for the selective control of weed grasses in newly sown leys, and the benefits to be gained from its use in terms of increased rye-grass dry matter yield has been widely reported. (Hammond et al. 1976, Griffiths et al. 1978, Haggar & Passman 1978, Griffiths & Hammond 1978, Goldsworthy et al. 1980).

Recent EEC agricultural policy changes have re-emphasised the need for the grassland farmer to improve grass management and productivity. The objective of the two years' work reported here has been to develop a cost effective wide spectrum herbicide based on a novel co-formulation of ethofumesate plus bromoxynil and ioxynil esters, (CR 16804), for use in new sown leys as a tool towards improving herbage quality, sward productivity and utilisation. This formulation has since been commercialised as 'Nortron Leyclene'[1].

MATERIALS AND METHODS

Eighteen small plot replicated trials on new sown leys were carried out in the United Kingdom during 1983/84 and 1984/85.

In addition, in 1983/84, a further 17 trials were conducted by farmers in unreplicated comparison with standard treatments. Although results from these trials are not presented in detail in this report they are in close agreement with the data from the small plot trials, and provide valuable corroborative evidence, particularly of weed species controlled.

An e.c. formulation (CR 16804) containing 200 g/l ethofumesate, and 50 g/l bromoxynil and 25 g/l ioxynil as iso-octyl esters was used, applied post-emergence in the autumn at a 'normal' dose of 5 l/ha in a volume of 200-220 l/ha. Comparative treatments were ethofumesate 200 g/l e.c. formulation ('Nortron' [2]) applied at 5 l/ha alone or in tank mixture with a co-formulated broad-leaved herbicide product ('Asset' [3]; 50 g/l benazolin, 62.5 g/l ioxynil and 125 g/l bromoxynil as esters) at 2 l/ha. Double and occasionally quadruple doses of ethofumesate based treatments were included in some trials for crop safety assessments.

Plot size in small plot randomised block design trials, was 8m x 2m replicated 4 times. Treatments were applied by knapsack sprayer. Large plot trials, generally 2 ha per treatment, were applied by farmers through their own machines.

Visual assessments of efficacy and crop safety were made throughout the season up until just before the first silage cut. Efficacy was assessed as a percentage score both for individual species and overall weed control, and crop safety as percentage vigour or scorch.

Five of the eight replicated trials laid down in autumn 1984 were taken to yield. Plots were cut by Merry Tiller fitted with a 1.0 m reciprocating blade. Total fresh weights were determined on site. 1.5 kg samples per plot were taken from each trial to the laboratory and there divided into three components: rye-grass, weed grasses and broad-leaved weeds. Each component was weighed before and after oven drying for 28 hours at 80°C. Aggregated yields for two silage cuts in 1985 are presented in terms of total and rye-grass d.m. values.

In the results tables weeds and volunteer crops are denoted in abbreviated form as below:

A.m.	Alopecurus myosuroides	M.sp.	Matricaria spp.
A.f.	Avena fatua	S.v.	Senecio vulgaris
H.v.	Hordeum vulgaris	S.m.	Stellaria media
T.a.	Triticum aestivum	U.u.	Urtica urens
P.a.	Poa annua	V.p.	Veronica persica
P.t.	Poa trivialis	V.a	Viola arvensis
C.p.b.	Capsella bursa-pastoris	V.f.	Vicia faba
L.p.	Lamium purpureum		

RESULTS

Weed Control

The performance of CR 16804 and standard treatments against annual weed grasses and volunteer cereals is compared in Tables 1 and 2. Mixed populations occurred at most sites, with 70% affected by Poa annua and some 35% by volunteer cereals, particularly Hordeum vulgaris. Applications were made at the early tillering stage of all species.

[1], [2], [3] Nortron Leyclene, Nortron and Asset are Registered Trade Marks of FBC Limited

TABLE 1

1983/84 Trials: Percentage Control of Annual Weeds Grasses (Pre-harvest Assessment)

Treatment	l/ha	P.a	P.t	A.m.	A.f.	H.v.	T.a.	Overall
CR 16804	5	88	54	92	30	97	76	83
CR 16804	10	89	64	99	87	97	81	91
ethofumesate + broad-leaved herbicide (t.m.)	5 + 2	89	55	93	73	98	78	84
ethofumesate + broad-leaved herbicide (t.m.)	10 + 2	94	70	99	83	98	84	92
Number of sites		7	2	2	1	4	2	8

(t.m.) tank mixture

TABLE 2

1984/85 Trials: Percentage Control of Annual Weed Grasses

Treatment	l/ha	4-12 WAT			12-20 WAT		
		H.v.	P.a.	A.m.	H.v.	P.a.	A.m.
CR 16804	5	65	66	75	83	72	92
CR 16804	10	69	74	80	90	90	96
ethofumesate	5	62	68	70	77	79	89
ethofumesate	10	67	73	79	89	90	96
ethofumesate + broad-leaved herbicide (t.m.)	5 + 2	68	64	79	86	83	94
Number of sites		5	6	2	5	6	2

Results against annual broad-leaved weeds are presented in Tables 3 and 4. Stellaria media was by far the most prevalent with more than 80% of trials affected. Matricaria spp., Veronica persica and Viola arvensis occurred at 30-40% of the sites. Weeds were at the seedling to young plant stage when sprayed.

TABLE 3

1983/84 Trials: Percentage Control of Annual Broad-Leaved Weeds (20-28 WAT)

Treatment	l/ha	S.m.	M.sp.	V.p.	V.a.	L.p.	S.v.	C.p.b.	Overall
CR 16804	5	97	84	99	87	91	100	95	92
CR 16804	10	99	78	99	87	84	100	100	93
ethofumesate + broad-leaved herbicide (t.m.)	5 + 2	100	82	88	91	70	100	99	92
ethofumesate + broad-leaved herbicide (t.m.)	10 + 2	100	87	98	74	82	100	100	95
Number of sites		9	4	5	3	2	2	1	9

TABLE 4

1984/85 Trials: Percentage Control of Annual Broad-leaved Weeds (12 WAT)

Treatment	l/ha	S.m.	M.sp.	C.p.b.	V.a.	V.p.	L.p.	Overall
CR 16804	5	93	100	96	18	95	80	96
CR 16804	10	97	100	95	31	98	95	98
ethofumesate	5	78	48	23	0	13	10	59
ethofumesate	10	86	61	26	2	21	8	66
ethofumesate + broad-leaved herbicide (t.m.)	5 + 2	99	100	100	31	94	85	99
Number of sites		5	5	3	2	3	2	

Crop Safety

The tolerance of rye-grass to CR 16804 and comparative treatments is shown in Tables 5 and 6.

TABLE 5

1983/84 Trials: Crop Safety (Mean of 10 Trials)

Treatment	l/ha	4 WAT				20-28 WAT			
		% Vigour		% Scorch		% Vigour		% Scorch	
		N	2N	N	2N	N	2N	N	2N
CR 16804	5	97	93	0.7	1.8	99	97	0	0
CR 16804	10	93	89	1.8	7.0	98	92	0	0
ethofumesate + broad-leaved herbicide (t.m.)	5 + 2	96	96	1.2	2.5	99	95	0	0
ethofumesate + broad-leaved herbicide (t.m.)	10 + 2	93	92	1.6	4.8	98	94	0	0

TABLE 6

1984/85 Trials: Crop Safety (% Vigour) Mean of 8 Trials

Treatment	l/ha	4-12 WAT	12-20 WAT
CR 16804	5	100	100
CR 16804	10	92.5	92.0
ethofumesate	5	99.7	100
ethofumesate	10	97.3	100
ethofumesate +broad-leaved herbicide (t.m.)	5 + 2	98.9	99.3

Yield

At the time of preparing this report two harvest cuts have been taken from five trials and the aggregated yields for each treatment are given in Table 9.

TABLE 9

1984/85 Trials: Rye grass and Total Dry Matter Yields as Percentage of Untreated (Aggregate of Two Cuts)

Treatment	l/ha	Breadsall		Reedham		Thrapston		Brickhill		Stoughton		Mean	
		a	b	a	b	a	b	a	b	a	b	a	b
CR 16804	5	99.2	95.6	102.7	99.1	136.3*	94.8	115.5*	106.5	103.4	88.4	110.3*	97.2
CR 16804	10	101.1	97.6	100.3	95.6	142.5*	95.2	114.4*	104.3	95	91.1	109.8*	96.9
ethofumesate	5	105.4	101.8	101.8	99.4	133.6*	96.0	118.5*	109.5	94.7	101.6	111.9*	101.2
ethofumesate	10	104.3	100.5	103.4	100.6	148.0*	100.4	109.9*	99.6	97.5	94.5	111.4*	99.2
ethofumesate+ broad-leaved herbicide (t.m.)	5 + 2	101.2	98.2	101.1	98.4	153.7*	107.5	114.4*	106.5	101.3	101.3	113.1*	102.4
% CV		5.9	5.8	8.6	8.9	9.4	10.3	8.4	10.8	9.3	13.0	9.2	10.0
untreated t/ha		3.0	3.1	3.5	3.6	2.4	3.6	2.4	2.6	1.9	2.0	2.6	3.0

* Significant difference from untreated (p = 0.05)
(a = Rye-grass d.m.)
(b = Total d.m.)

DISCUSSION

Analysis of the two years' results shows that the level of weed grass and volunteer cereal control achieved by treatments was dependent on the ethofumesate dose, and at equivalent rates CR 16804 gave similar control to the standard treatments. Treatments containing 1.0 kg ai/ha ethofumesate gave good control of P. annua, A. myosuroides, and volunteer barley, whilst P. trivialis, A. fatua and volunteer wheat were well suppressed. However, 2.0 kg ai/ha of ethofumesate was required to give consistently good control of all species (Tables 1 and 2).

Speed of broad-leaved weed response to herbicide treatments was initially rather slow, reflecting the generally cold conditions at or after application. The ethofumesate plus broad-leaved herbicide tank mixture tended to be quicker than CR 16804, but both were clearly superior to ethofumesate alone even against S. media (Table 4).

Assessment in the spring, before the first harvest cut, showed that both CR 16804 and the tank mixture treatment had performed similarly well against a wide spectrum of broad-leaved weeds with no regrowth. As anticipated these treatments were much superior to ethofumesate which predictably gave acceptable control of S. media but was inadequate against other broad-leaved species occurring in the trials.

The excellent margin of crop safety with CR 16804 is well demonstrated in the 1983/84 replicated trials (Table 5). In these trials up to a quadruple dose of CR 16804 was applied in comparison with the tank mixture. Initially all treatments caused dose related crop scorch and vigour loss, particularly when frost followed application, but none was unacceptably phytotoxic. Scorch symptoms were quickly outgrown and by spring only quadruple dose plots were still noticeably suffering from vigour loss.

Statistical analysis of aggregated rye-grass d.m. yields across the five harvested trials shows a significant increase (5% level) for all herbicide treatments. The increases, which ranged between 10% and 13% over untreated appear to reflect weed grass control by ethofumesate and are not dose related. Since mean untreated ryegrass yield was 2.6 tonnes d.m./ha the benefit from herbicide treatment ranged between 0.26 and 0.3 tonnes d.m./ha.

There was a wide diversity in sward composition within the trials at the time of the first harvest cut, and at two (Thrapston and Brickhill) there were sufficiently heavy populations of weeds (42.5% and 17% respectively of total sward) for the yield benefits from herbicide treatment to be statistically significant. At Thrapston aggregated ryegrass yield increases for herbicide treatments ranged from 34% to 48% (0.8 to 1.2 tonnes d.m./ha) and at Brickhill 10% to 18.5% (0.24 to 0.44 tonnes d.m./ha). Total d.m. yields were not increased by herbicide treatment.

The results of the two years' trials demonstrate CR 16804 to be a very effective and safe herbicide for use in grass. Its introduction into the United Kingdom market in 1984 has provided the grassland farmer with a cost-effective wide spectrum post-emergence treatment for use on rye-grasses and other crop grasses e.g fescues, Timothy and Cocksfoot during the establishment phase. A 5 l/ha dose of the product applying 1.0 kg ai ethofumesate, 0.25 kg ai bromoxynil and 0.125 kg ai ioxynil/ha gives consistent and reliable control of a wide spectrum of broad-leaved weeds, Poa. annua and good suppression of other annual weed grasses and volunteer cereals.

ACKNOWLEDGEMENTS

The Authors wish to thank their colleagues who conducted the trials in this project and the many farmers who provided the facilities for the work to be carried out.

REFFERENCES

Goldsworthy, J. A.; Duke, L. G.; Whitehead, R. (1980) Control of weed grasses and Stellaria media in grass with ethofumesate. Proceedings 1980 British Crop Protection Conference - Weeds, 2, 483-488

Griffiths, W.; Hammond, C. H. (1978) Establishing weed free swards. Changes in Swards Composition and Productivity, A. H. Charles and R. J. Haggar (eds.), Occasional Symposium No. 10, British Grassland Society, Hurley, 191-197

Griffiths, W.; Hammond, C. H; Edwards, C. J. (1978) Weed control in new leys and established pastures with ethofumesate, Proceedings 14th British Weed Control Conference, 1, 309-316

Haggar, R. J.; Passman, A. (1978) Some consequences of controlling Poa annua in newly sown ryegrass leys. Proceedings 1978 British Crop Protection Conference - Weeds, 1, 301-304

Hammond, C. H.; Griffiths, W.; van Hoogstraten, S. D.; Whiteoak, R. J. (1976) The use of ethofumesate in grass seed crops, Proceedings 13th British Weed Control Conference, 2, 657-663

THE SIGNIFICANCE OF CLOVER AND ASSOCIATED WEED PROBLEMS IN GRASSLAND

J JOHNSON

Agricultural Development and Advisory Service, Government Buildings, Lawnswood, Leeds LS16 5PY

C DIBB

Agricultural Development and Advisory Service, Government Buildings, Coley Park, Reading RG1 6DT

ABSTRACT

White clover currently appears to perform a less important role than in the past in forage production systems. Recent evidence suggests higher animal intake and performance on clover based swards compared with all grass swards. However its lower total yield and greater variability compared with grass receiving fertiliser nitrogen may restrict white clover exploitation to less intensive beef and sheep grazing systems. This is especially true in the uplands, although more recent evidence suggests a potential role in conservation systems. Guidelines are available for ensuring satisfactory establishment but there remain problems with controlling weeds, particularly Poa annua and Stellaria media in late summer sown leys.

INTRODUCTION

The role of the ley with a vigorous content of red and white clovers was greatly valued in the first half of this century not only for its contribution to herbage production but also for its nitrogen contribution to subsequent cereal crops. The Stapledon doctrine of ploughing and reseeding with grass/clover swards at regular intervals, although appropriate for arable farming systems, has less application in areas of adverse climate and difficult soils where grass is grown continuously (Lazenby 1981).

The relative cheapness of inorganic nitrogen in recent years has resulted in a continued increase in its use and a reduced need for legumes in arable systems. This has put the continued survival and utilisation of white clover in grassland systems in jeopardy.

This paper considers the contribution of white clover in swards, comments on the establishment of white clover in reseeds and existing swards, and concludes with reference to current herbicide use on legume based swards.

SIGNIFICANCE OF WHITE CLOVER IN LOWLAND AND UPLAND PASTURES

Demand for white clover seed in the UK has remained fairly steady at around 1000 tonnes annually during the last 25 years, although the proportion derived from home grown sources is now less than 5%, due to wide variation in yield experienced by clover seed growers and the relative cheapness of imported varieties, especially from New Zealand (Hides, Lewis & Marshall 1985). As white clover is sown in the vast majority of seeds mixtures (Anon 1) and in view of the fact that over 400,000 hectares of grassland are reseeded annually in Great Britain a reasonable level of white clover in pastures could be assumed.

The National Farm Study (Forbes et al. 1980) indicated that a good content of white clover, defined as a well distributed population contributing over 5% of ground cover, was recorded on only 9% of fields on dairy farms, 24% of fields on non-suckler beef farms, and 30% of fields on suckler beef farms. In addition there was a tendency for clover contribution to decline as swards aged (Table 3).

TABLE 3

Proportions of sward with a good content of clover, within age groups and farm types:

% farms in each group

Age	Dairy Farms	Non Suckler Beef Farms	Suckler Beef Farms	All Farms
1-4 years	13	34	41	25
5-8 years	8	27	34	20
9-20 years	6	22	39	21
Over 20 years	7	22	23	16
All ages	9	24	30	19

A re-survey in 1983 of farms listed in the National Farm Study in three districts in S W England has shown a further decline in the level of white clover (Peel 1985, Personal Communication) as nitrogen use on grass has almost doubled since 1974.

Although there tends to be a higher contribution of white clover in the hills and uplands (Younie & Black 1979, Swift et al. 1981) problems of ensuring satisfactory white clover establishment remain. These are further aggravated by low levels of suitable Rhizobia especially when improving deep peat soils.

Whilst the criteria for success of establishment in the uplands must necessarily be less exacting than in the lowlands, in some instances only 10% of clover seed may establish following surface seeding in dry years. Once established however the upland system of severe spring grazing to reduce grass competktion and the low levels of fertiliser nitrogen applied (50-100 kg/ha N) should allow for greater clover significance. Redesdale Experimental Husbandry Farm, for example, has managed to maintain clover contents at around 20% in July on a sward reseeded nearly 10 years ago (ADAS 1985) and provided on average a 40% increase in yield compared with pure grass swards (Davies 1984).

The nitrogen contribution of white clover on hill land has only recently been defined (Munro 1981) - a small leaved white clover in a mixed ryegrass sward contributed nearly 100 kg/ha N, and this approximated to the theoretical potential based on temperature.

ENSURING SUCCESSFUL CLOVER ESTABLISHMENT

Reseeds

Haggar et al. (1985) suggest an establishment level of about 150 plants m^{2} 12 weeks after sowing to give a ground cover of 30% a year later. A reasonable correlation exists between yield in the first year and yield in subsequent years (Morrison 1985).

A typical seed rate for a long term ryegrass white clover ley would be 20 kg/ha of perennial ryegrass and 2.5 kg/ha of clover, providing approximately 10 million ryegrass and 4 million clover seeds which even allowing for 50% mortality should provide adequate numbers of seedlings for successful establishment.

The low level of white clover referred to could be due to a variety of reasons recently noted (Scott & Johnson 1983). The increased tendency towards autumn sowing, often too late and too deep, affects clover more than grass. In three trials broadcasting the clover increased the number of plants established 5-6 weeks after sowing by an average of 14% for a spring sown trial and 27% for the autumn sown trials. Reducing grass seed rate increased clover establishment markedly four months after sowing in spring (Table 4).

TABLE 4

Effect of grass seed rate on % cover of white clover and perennial ryegrass four months after sowing in spring

	Grass Seed Rate (kg/ha)			
	20	10	5	2.5
% clover cover	7	10	16	24
% ryegrass cover	82	78	66	56
% other grass cover	1	2	4	7

Broadcasting the clover rather than drilling increased ground cover by 50% and this was further increased by a higher clover seed rate. From this and other work guidelines for white clover establishment in reseeds have been produced (Tedstone 1985):

- sow from April to August at the latest, direct spring sowing best
- ensure pH 6.0, and at least 5.5 on peaty soil (Rhizobia needed on peaty soil)
- firm Cambridge rolled seedbed
- 4:1 grass: clover seed rate, with a minimum of 3 kg/ha of clover
- broadcast seed, light harrow, flat roll
- control weeds as necessary using clover safe herbicides.

Existing swards

The introduction of white clover into existing swards is currently being studied at AGRI, North Wyke (Sheldrick et al. 1984). Several direct drills or seeders are capable of providing good conditions for germination of over-sown clover seeds but it has often been found that despite good initial germination white clover does not develop to become a major sward component (eg Dibb et al. 1981). Initial establishment at North Wyke following a July oversowing with a Hunter strip-seeder was good over a range of autumn/winter grazing treatments. Management during the spring/early summer was critical with a much increased ground cover of white clover in early August in the swards which had been cut, as distinct from those continuously grazed. It is likely that the harmful effect of grazing is derived more from the June/July period than during April and May when it is traditional to graze grass/white clover swards tightly to enhance clover growth and seed production during June to August (Haggar & Holmes, 1963).

The establishment of white clover in ley farming using techniques of complete reseeding is much better researched and understood than the establishment and development of white clover in established grass swards where reliable guidelines are long overdue.

Conservation systems

In addition to the significant place of white clover as the major source of nitrogen on less intensive lowland and upland grazing systems there is also potential in conservation systems. Frame (1985) compared a system based on two simulated grazings and two cuts without nitrogen with a similar system receiving a spring dressing of 75 kg/ha N only. The nil nitrogen treatment gave a total herbage yield of 9.2 t DM/ha with a 52% white clover contribution and the nitrogen treatment gave 10.1 t DM/ha in total but only 28% white clover. Results of the Grassland Manuring (GM) trial support this (Table 5). The closing up of a grazing field not receiving fertiliser nitrogen can increase stolon density and is a recommended periodic management practice (Morrison et al. 1985).

TABLE 5

Yields of grass/white clover swards cut for conservation (t/DM/ha)

N (kg/ha)	Cut 1 end May	Cut 2 end July	Total
0	3.8 (42)	2.7 (66)	6.5
100	5.3 (19)	2.5 (5)	7.8
	( ) % clover		

Varieties

Variety choice is restricted by seed supply. A range of varieties exists from small leaved profusely branching Kent wild white and S184, suitable for intensive continuous sheep grazing at low levels of fertiliser nitrogen, to medium-large leaved and less branching varieties such as Blanca for which a conservation system with some fertiliser nitrogen would be more appropriate. In practice the intermediate variety Grasslands Huia is sown most widely due to its relative cheapness, with a proportion of one of the two contrasting types depending on management systems (Anon 1 1985).

NUTRITIVE VALUE OF WHITE CLOVER

This has been fully researched and reviewed by Thomson (1984). White clover contains half the cell wall and 50% more protein than perennial ryegrass of the same digestibility. In addition, as it matures its decline in digestibility is much less than that of grass.

Sheep, cattle and dairy cows consume ad lib at least 20% more dry matter of clover than grass. The potential benefits of white clover are greatest with sheep. On average their rate of liveweight gain was 65% when fed clover ad lib compared with grass. For cattle there was an 18% increase and in a total lactation experiment cows grazing ad lib clover gave a 20% higher yield than cows grazing grass. Thomson concluded that with mixtures, linear response in growth rate and milk yield had been measured when clover had been included with grass. He recommended that a mixed sward should be managed so that clover contributed on average not less than 30% of the dry matter. Similarly the potential nutritive value of other legumes such as red clover and lucerne is high when compared with perennial ryegrass (Campling 1984).

WHITE CLOVER IN FARMING SYSTEMS

The potential dry matter yield of clover based swards is lower than that of swards receiving fertiliser nitrogen. In a national ADAS experiment (GM 23), on average, grass/white clover swards without fertiliser nitrogen yielded as well (7.5 t DM/ha) as grass receiving 200 kg/ha N but only 70% of grass receiving optimum rates of fertiliser nitrogen (Doyle et al. 1984). In addition white clover tended to have greater variability between sites and between years than grass.

This inherently lower yield potential of grass/white clover swards combined with greater variability when compared with grass/nitrogen systems is a major constraint in exploiting the use of white clover under intensive livestock systems. There remains a role, however for white clover based swards not only under less intensive beef and sheep in the lowlands, but particularly in the uplands. Successful systems have been described.

Stewart & Haycock (1983) compared, over 6 production cycles, a 18 month beef system based on grass/white clover (50 kg N annually) with grass at 300 kg N/ha. The latter produced 21% more carcase gain and a better gross margin/ha but when allowance was made for operating the system and for interest charges the low N system proved to be as profitable as the high N system and needed less working capital.

There is little information on legume based intensive sheep systems. Newton et al. (1984) compared rotational and continuous grazing at low and high stocking rates of grass/clover swards and grass swards receiving 200 kg/ha N. Whilst stocking rate had an overriding effect on production of lamb per hectare, where the two swards were compared at the same stocking rate the faster growth rate of lambs gave the clover the advantage. Rotational grazing systems were preferable to continuous grazing in terms of maintaining clover levels.

Passmore & Dibb (1984) described a viable system for beef and sheep based on a three year grass/legume ley in an arable rotation which gave a gross margin similar to the average of the Meat and Livestock Commission top third producers.

Doyle et al. (1984), after reviewing the cost benefits from exploiting white clover in a range of livestock systems, concluded the potential benefits are greatest where fertiliser nitrogen use is below 200 kg/ha (especially for beef cattle and sheep) but above 300 kg/ha N the advantage of switching to grass/clover are small. Fertiliser nitrogen price would need to rise sharply relative to other inputs for legumes to become more attractive. In a national context however, Wilkins et al. (1981) indicated that legume based forage production could sustain the current ruminant output.

ASSOCIATED WEED PROBLEMS

In arable rotations the practice or spring undersowing of a light cereal crop has declined. This is due in part to the increased area of winter cereal but also because of the need to optimise the yield of a spring cereal. Where clover is valued, however, the practice of undersowing will doubtless continue and in this situation weeds can generally be controlled effectively (Boughton et al. 1982). Elsewhere early cereal harvest and adequate arable expertise should allow for satisfactory establishment of the ley to give clover a good chance of survival. In many cases sowing in autumn, to the detriment of the clover, may be of little concern to the predominantly arable farmer who may be exploiting short term leys with heavy dressings of fertiliser nitrogen.

In grassland areas, however, late summer is often the only time when there is sufficient slack in the system to allow for reseeding, and the lack of practice in reseeding allied to inherent difficulties of soil and climate often found on these farms, can result in poor establishment, particularly of clover, and increased weed problems.

The weed problems associated with arable and grassland systems have recently been summarised (Haggar et al. 1985). Grass weeds are most frequent in arable-grass sowings and dicotyledenous weeds most common in grass to grass reseedings, but with Stellaria media and Poa annua common to both.

These weeds can, on occasions, reach massive proportions. Younie et al. (1984) quoted a level of 10,000 P.annua seedlings/m^2 in a trial in Aberdeen. At much lower levels these can seriously affect the tillering of ryegrass (Haggar & Passmore 1978) but there is no information on its effect on the development of white clover. Attempts in the field to improve white clover establishment by a reduction in grass seed rate, resulted in an increase in grass weeds (Scott & Johnson 1983) and also in chickweed growth (Haggar et al. 1985) where even at a S.media density of 25 plants/m^2, the ground cover of ryegrass was halved and that of clover reduced to only one sixth of its level in the absence of S.media (Table 6).

TABLE 6

Effect of S.media density and grass seed rate on species components

Species	S.media plants m^{-2}					Seed rate		
	0	10	15	25	s.e.	low	high	s.e.
Ground cover %								
Ryegrass	68	45	43	37	5.1	34	62	3.6
White clover	6	2	1	1	0.8	3	1	0.5
S.media	0	39	50	61	5.6	42	33	3.9
P.annua	21	8	5	1	2.7	14	3	1.9
Tillers, leaves m^{-2}								
Ryegrass	813	589	610	546	52	476	803	37
White clover	197	52	34	46	21	109	55	15

This would suggest that S.media populations as low as 10/m^2 should be controlled if the long term survival of clover is to be assured.

The trend towards late summer sowing continues to pose problems of weed control in clovery leys. None of the herbicides claiming clover safety can be recommended for use until the plant has at least one trifoliate leaf (Anon 2 1984) and this may not be reached until after October which may be later than the recommended application time (Kirkham et al. 1984) who delayed spraying in the hope of allowing the clover to reach the less vulnerable growth stage before spraying a range of chemical treatments in two trials. In the first trial, a ryegrass/white clover ley, all the herbicides (bentazone, benazolin, bentazone plus benazolin, mecoprop, bentazone + MCPB + MCPA, benazolin + 2, 4-DB + MCPA) controlled S.media, but only benazolin and bentazone increased the clover content compared with unsprayed plots. In the second trial carried out on monocultures of perennial ryegrass, white clover and S.media, bentazone again controlled S.media and did not damage the clover or ryegrass, but bentazone + MCPB + MCPA damaged the clover without controlling the S.media. A mixture of benazolin + 2, 4-DB + MCPA damaged the clover in the first experiment but not the second. Both mixtures controlled a wider range of weeds than bentazone, although further work indicated reduced clover establishment 11 months after spraying. Kirkham et al. (1984) concluded that bentazone would give effective clover safe S.media control resulting in better clover survival than the commercial mixtures mentioned. The cost of the rate of chemical needed (£30/ha for the 1 kg ai in experiment 2) may however preclude its use as herbicide cost is an important consideration as to which is used. Work by ADAS (Cooper & Jackson 1985) has attempted to extend the safe period of commercial products which will control S.media without adverse effects on clover. A summary of results for selected chemicals is shown in Table 7.

TABLE 7

Effect of herbicide timing on S.media control (%) and clover survival (%) (mean of 9 sites)

Chemical	Rate kg ai/ha	S.media Control % Autumn	Early Winter	Late Winter	Clover Suvival % Autumn	Early Winter	Late Winter
bentazone + MCPB + MCPA (i)	1.0 + 1.0	64	45	71	40	60	71
bentazone + MCPB + MCPA + cyanazine	2.4 + 0.20	93	61	76	21	67	29
benazolin + 2,4-DB + MCPA (ii)	2.18	93	65	42	41	87	49
Untreated control	-	Nil	Nil	Nil	100	100	100

Autumn - to 15 November
Early winter - 16 Nov-31 Dec
Late winter - 1 Jan-31 Mar

(i) product Acumen
(ii) product Fortrol

The results refer to a mean of two years, the first of which (1982/3) was characterised by generally good clover survival but the reverse was the case the following year. In both years universally poor survival experienced with the early autumn treatment was associated with severe frosts prior to or soon after spraying in one year. This loss of clover due to herbicide damage can be aggravated by clover loss even on unsprayed areas (Table 8). Clover survival therefore appears largely dependent on sowing date. More recent work (ADAS unpublished) may offer some promise of improved formulation to increase clover safely.

TABLE 8

Effect of sowing date on % clover plant survival

Sowing date	4 February	19 March
16 August	91	66
30 August	72	48
14 September	79	50
1 October	58	8

Clover safety to herbicides in past may have been based on the survival of a few plants after spraying or volunteer plants from "hard" seeds (which can constitute up to 15% of seed sown), up to one-third of which will germinate within a year (Spedding & Diekmahns 1972).

There is therefore uncertainty regarding causes of clover loss. It is important for herbicide manufacturers to define more closely the effects of their products on the clover population. In addition farmers should appreciate the need to sow early enough to ensure clover survival even in the absence of herbicides.

CONCLUSION

On balance those wishing to rely on white clover should concentrate on spring seeding, either direct or undersown, when herbicide effects may be less pronounced and post emergence development is likely to be quicker than when sown in late summer. The sowing of a pure stand of clover in spring and the slot seeding of ryegrass in late summer (Haggar et al. 1985) is a novel approach that may merit consideration. Similarly the sowing of clover in spring into an autumn sowing of grass could be studied. Those sowing white clover in late summer may have to accept that a combination of climate, chemicals and other factors can have significant adverse effects on their aspirations to establish and manage clover dominant swards.

REFERENCES

ADAS (1985) Redesdale EHF Annual Review

Anon (1) (1984) Agricultural Development and Advisory Service. Weed Control in Grassland, Herbage Legumes and Grass Seed.

Anon (2) (1985) Agricultural Development and Advisory Service. Seed Mixtures. Booklet 2041, MAFF Publications.

Boughton, D.N., Woodcock, P.M., Cooper, F.B., Johnson, J., (1982). Broad leaved weed control and safety of bentazone mixtures used in undersown cereals and direct sown leys. Proceedings 1982 British Crop Protection Conference - Weeds I, 363-367.

Campling, R.C., (1984) Lucerne, red clover and forage peas: management, utilisation and incorporation into farming systems. In: Forage Legumes, B.G.S. Occ. Symp. No 16, Ed. D.J. Thomson.

Cooper, F.B., Jackson, M.V., (1985) Experiments in controlling chickweed with various selective herbicides. B.C.P.C./B.G.S. Symposium on Weed, Pests and Diseases of Grassland, Nottingham 1985 (in Press).

Davies, M.H., (1984) Production from white clover on hill land. In: Forage Legumes. B.G.S. Occ. Symp. No 16, Ed. D.J. Thomson.

Dibb, C., (1981) The British Grassland Society, Dorset Site: Summary of paper presented at B.G.S. Winter Meeting Dec. 1980. Grass and Forage Science 36, 2, 135-137.

Doyle, C.J., Morrison, J., Brockman, J.S., Camm, B.M., Reeks, J., (1984) Practical potential of legumes: and economic assessment in Forage Legumes, B.G.S., Occ. Symp. No 16, Ed. D.J. Thomson.

Forbes, T.J., Dibb, C., Green, J.O., Hopkins, A., Peel, S., (1980) Factors affecting the Productivity of Permanent Grassland: A National Farm Study.

Haggar, R.J., Holmes, W., (1963) Kent wild white clover. Report from Department of Agriculture, Wye College, Ashford, Kent.

Haggar, R.J., Passman, A., (1978) Some consequences of controlling Poa annua in newly sown ryegrass leys. Proceedings 1978 British Crop Protection Conference - Weeds I, 301-308.

Haggar, R.J., Standell, C.J., Birnie, J.E., (1985) Occurrence, impact and control of weeds in newly sown leys. B.C.P.C./B.G.S. Symposium on Weeds, Pests and Diseases of Grassland, Nottingham 1985 (in Press).

Hides, D.H., Lewis, J., Marshall, A., (1984) Prospects for white clover seed production in the UK. In: Forage Legumes B.G.S. Occ. Symp. No 16 Ed. D.J. Thomson.

Kirkham, F.W., Birnie, J.E., Haggar, R.J., (1984) Late autumn control of chickweed in newly sown ryegrass/white clover leys. In: Forage Legumes B.G.S. Occ. Symp. No 16, Ed. D.J. Thomson.

Lazenby, A., (1981) British grassland; past, present and future (Review Paper) Grass and Forage Science 36, 4, 243-266.

Morrison, J., (1985) Factors affecting grass clover swards. 3rd White Clover Discussion Group. Hurley, August 195.

Morrison, J., Newton, J.E., Sheldrick, R.D., (1985) Management and utilisation of white clover. AGRI information leaflet No 14.

Munro, J.M.M., (1981) The Introduction of improved plant resources. In: The Effective use of forage and animal resources in the hills and uplands. B.G.S. Occ., Symp., No 12, Ed. J. Frame.

Passmore, C.W., Dibb, C., (1984) A traditional grass/legume ley for modern farming. In: Forage Legumes B.G.S., Occ., Symp., No 16, Ed. D.J. Thomson.

Scott, J.L., Johnson, J., (1983) White clover establishment. Summary of paper presented at B.G.S. Winter Meeting Dec. 1982. Grass and Forage Science 38, 2 152-153.

Sheldrick, R.D., Lavender, R.H., Parkinson, A.E., (1984) Introduction of white clover into existing swards. Ann. Rep. Grassl. Res. Inst. 1983-4, 76-77.

Spedding, C.R.W., Diekmahns, (1972) Grasses and Legumes in British Agriculture. Commonwealth Agricultural Bureaux.

Stewart, T.A., Haycock, R.E., (1983) Beef from white clover/grass or high N grass swards - production results from a 6 year comparison. Agriculture in N. Ireland 58, 37-43.

Swift, G., Holmes, J.C., Wood, Jean, Morris, R.J.F., (1981) The Grassland of East Scotland. In: The effective use of forage and animal resources in the hills and uplands. B.G.S., Occ., Symp., No 12, Ed. J. Frame.

Tedstone, G.E.C., (1984) Syndicate report - White Clover. In: Forage Legumes, B.G.S., Occ., Symp., No 16, Ed. D.J. Thomson.

Thomson, D.J., (1984) The nutritive value of white clover. In: Forage Legumes, B.G.S., Occ., Symp., No 16, Ed. D.J. Thomson.

Younie, D., Black, J.S., (1979) A survey of surface seeded swards in crofting areas of Northern Scotland. N.O.S.C.A., Bulletin No 16.

THE SAFETY AND EFFICACY OF BENAZOLIN MIXTURES FOR WEED CONTROL IN GRASS/CLOVER SWARDS.

J MARSHALL, R J AYRES

FBC Limited, Nottingham Road, Stapleford, Notts NG9 8AJ

ABSTRACT

Most grass/clover swards are drilled in the late summer or early autumn and there is an increasing need for a broad-leaved weedkiller which is effective and clover-safe under cool conditions.

This paper compares the efficacy of two experimental formulations of benazolin + 2,4-DB + MCPA with that of the commercially available product.

The results presented show that, compared to the commercial product, broad-leaved weed control, especially of *Stellaria media*, can be improved by increasing the dose/ha of benazolin. Clover safety can be improved compared to the commercial product by reducing the doses/ha of 2,4-DB and MCPA.

INTRODUCTION

Benazolin mixtures have been widely used in grass/clover swards since their introduction in 1965. These mixtures were developed primarily for use in the spring on spring drilled grass/clover or on grass/clover undersown in spring barley and, until 1984, were not recommended for use later than the end of August.

Since the introduction of benazolin mixtures farming practices have changed dramatically and most grass/clover leys are now direct drilled in the early autumn. A recent survey (PAR 1984 - private study) shows that in England and Wales 70% of all leys are autumn sown. In Scotland 90% of leys are still sown in the spring but this is changing with the increase in importance of winter barley. The change to autumn sowing meant that in many situations it was not possible to use benazolin mixtures, within label recomendations, for broad-leaved weed control until the spring. By this time weeds were often large and difficult to control.

In practice farmers and advisors were reluctant to wait until the spring and used benazolin mixtures, usually successfully, into the late autumn. Trials in England and Scotland (Richards *et al* 1984, Lake 1984) showed that a mixture of benazolin + 2,4D-B + MCPA (Legumex Extra) was 'safe' to clovers when applied in late autumn and in 1984 FBC Limited introduced a recommendation for the use of this mixture up to the end of October.

Stellaria media is the most common and competitive broad-leaved weed in autumn sown grass/clover (Haggar and Kirkham 1981) and can be difficult to control in cool conditions with herbicides safe to clover. (Richards et al 1984) In autumn 1984 trials were conducted in new grass/clover leys in England and Scotland with the commercially available formulation of benazolin + 2,4-DB + MCPA and two modified formulations. The objectives were to improve S. media control in cool conditions by increasing the dose of benazolin and/or to improve clover safety by reducing the dose of MCPA and 2,4-DB. Results from these experiments are summarized in this paper

MATERIAL AND METHODS

Herbicides used were:-

benazolin 27g + 2,4-DB 237g + MCPA 43g a.i./l
aqueous formulation 'Legumex Extra' (1)

benazolin 36g + 2,4-DB 237g + MCPA 43g a.i./l
aqueous formulation CR 17140

benazolin 50g + 2,4-DB 237g + MCPA 43g a.i./l
aqueous formulation CR 17139

bentazone 200g + MCPB 200g + MCPA 80g a.i./l

aqueous formulation 'Acumen' (2)

linuron 30g + 2,4-DB butyl ester 220g + MCPA iso-octyl ester 30g a.i./l emulsifiable concentrate 'Alistell' (3)

cyanazine 500g a.i./l suspension concentrate 'Fortrol' (4)

Treatment details and timings are given in Tables 1 - 3

Seven trials were conducted in commercial rye grass/white clover leys drilled in autumn 1984. Herbicide treatments were applied in the autumn (mid to late October) or in the spring (March/April) using Drake and Fletcher knapsack sprayers calibrated to deliver 200l/ha through flat-fan nozzles at a pressure of 280 - 300 Pa. Treatments were replicated four times in a complete randomized block design. Plots were 10m long and 2m wide.

Crop-stage and size, grass and clover, and weed size and ground cover were recorded before each spray timing. Visual assessments of crop safety and weed control, by biomass, were made at intervals through the season. Final assessments were made in late April - early May before crops were grazed or cut for silage.

RESULTS

Broad-leaved weed control

Trial sites had a wide spectrum of annual broad leaved weeds in the autumn but relatively few species survived in appreciable numbers into the spring.

All treatments, except bentazone + MCPB + MCPA applied in the autumn, gave good broad-leaved weed control (Table 1) S.media was by far the most common weed and predominated at all sites. Autumn treatments of CR 17139, CR 17140 and linuron + 2,4-DB + MCPA gave similar, good control of S. media, better than the benazolin + 2,4-DB + MCPA standard and other treatments. Spring treatments applied to larger weeds proved less effective than the equivalent autumn treatments, with the exception of bentazone + MCPB + MCPA. In the spring CR 17139 and CR 17140 proved more effective against S. media than all other treatments but less effective than bentazone + MCPB + MCPA ± cyanazine against Veronica persica, Matricaria perforata and Myosotis arvensis.

Clover safety

All treatments caused some reduction in clover vigour and at four sites kill was recorded (Table 2).

Despite hard winter conditions autumn treatments to small clover plants proved safer than the corresponding spring treatments to larger plants.

Assessed four weeks after treatment in the autumn benazolin + 2,4-DB + MCPA mixtures proved much safer at normal (N) and twice normal (2N) doses than bentazone + MCPB + MCPA ± cyanazine or linuron + 2,4-DB + MCPA at N dose. By the spring, clovers treated with benazolin + 2,4-DB + MCPA mixtures showed good and usually complete recovery from the initial check (Table 2).

Bentazone + MCPB + MCPA ± cyanazine and linuron + 2,4-DB + MCPA caused greater initial damage and recovery was sometimes incomplete at the final assessment in April-May. Spring applications of all treatments proved more damaging to clover than the corresponding autumn treatments and recovery was incomplete at the final assessment. Differences between treatments were less marked than in the autumn but again benazolin + 2,4-DB + MCPA mixtures were safer than other treatments. CR 17139 which delivered less MCPA and 2,4-DB than other benazolin mixtures proved relatively 'safe' when applied either autumn or spring.

Grass safety

All the mixtures tested showed acceptable to good safety to grass when applied in the autumn and spring at normal recommended doses (Table 3). Benazolin + 2,4-DB + MCPA proved very safe to grass at both N and 2N doses, autumn and spring. Linuron + 2,4-DB + MCPA caused yellowing of the foliage and slight loss of vigour when applied in the autumn but recovery was rapid from the recommended dose.

DISCUSSION

The results presented confirm the decision taken in 1984 to recommend the use of benazolin + 2,4-DB + MCPA in new grass/clover swards in the autumn up to the end of October. Autumn treatment has, in fact, proved safer to clover and more effective against broad-leaved weeds than an equivalent spring treatment. Similar results have been recorded by other workers. (Boughton et al, 1982 Richards et al, 1984)

In our trials all benazolin + 2,4-DB + MCPA mixtures proved safer to white clover, in the autumn or spring, than bentazone + MCPB + MCPA or linuron + 2,4-DB + MCPA. Similar results have been recorded elsewhere (Boughton et al 1982). Increasing the dose of benazolin to 250g a.i/ha (CR 17140) compared to 189g ai/ha in the present commercial product has given much improved control of *S. media* and some other weeds with little adverse effect on clover safety. CR17139, which delivers 250 g ai/ha of benazolin but lower doses of 2,4-DB and MCPA than the commercial product, gave improved weed control, especially of *S. media* and also improved clover safety.

Both new benazolin mixtures (CR17139 and CR17140) show promise and further trials are planned for autumn 1985. Objectives are to confirm the improvement in weed control and clover safety and, if possible, to extend spray timing recommendations beyond the end of October.

ACKNOWLEDGEMENTS

The authors wish to thank their colleagues involved in the execution of these trials and the farmers on whose land the trials were carried out.

REFERENCES

Haggar, R.J ; Kirkham, F W ; (1981) Selective herbicides for establishing weed-free grass. 1. Evaluation of ethofumesate and methabenzthiazuron. Weed Research 21, 141 -15

Lake, C.T. (1984) Control of broad-leaved weeds in seedling grassland and undersown cereals with a new formulation of linuron, 2,4D-B and MCPA. Proceedings 1984 Crop Protection in Northern Britain, 321 - 325

Richards, M.C.; Swift, G; Davies D.H.K.; Cleland, A.T. (1984). An assessment of common chickweed (Stellaria media) control and safety to sown species of a range of herbicides in autumn sown leys. Proceedings 1984 Crop Protection in Northern Britain 333 - 338

Psychometric Attitudes Research 1984. Private study.

(1) Legumex is a registered trade mark of FBC Limited

(2) Acumen is a trade mark of BASF

(3) Alistell is a trade mark of Farm Protection Limited

(4) Fortrol is a trade mark and product of Shell

6353/5

TABLE 1

Treatments, dose (product/ha), timing and mean percent weed control in May

Treatment	l/ha	Timing	S.media	V.persica	M.perforata	M.arvensis	Overall
benazolin + 2,4-DB +MCPA	7	a	82	60	100	45	79
		s	69	55	72	45	72
CR 17139	5	a	91	65	100	59	89
		s	82	57	48	52	78
CR 17140	7	a	92	85	100	51	89
		s	83	60	70	51	81
bentazone + MCPB +MCPA	5	a	46	75	100	40	53
		s	71	82	63	60	75
bentazone + MCPB + MCPA	5	a	82	90	100	74	83
+ cyanazine	0.3	s	75	100	82	70	81
linuron + 2,4-DB +MCPA	3.5	a	91	50	80	75	84
		s	72	75	82	70	74
weed size at spraying (cm)		a	5-20	5	6	2-8	-
		s	20-40	30	15	8-10	-
No. of trials			7	2	1	2	7

a = October s = April

TABLE 2

Treatments, dose (product/ha), timing and mean percent crop effects (clover) 4 WAT and May

Treatment	l/ha	Timing	Mean % Kill N dose	Mean % Kill 2 N dose	Mean % Vigour N dose	Mean % Vigour 2 N dose	Mean % Vigour May N dose	Mean % Vigour May 2 N dose
benazolin + 2,4-DB + MCPA	7	a	4	19	91	86	101	83
		s	29	57	71	30	71	30
CR 17139	5	a	3	17	93	80	101	73
		s	20	43	95	47	95	47
CR 17140	7	a	5	20	95	47	87	86
		s	35	61	91	82	86	43
bentazone + MCPB + MCPA	5	a	25	42	69	66	68	65
		s	20	66	76	70	70	70
bentazone +MCPB + MCPA	5	a	41	45	69	72	61	65
+ cyanazine	0.3	s	60	80	61	10	61	10
linuron + 2,4-DB +MCPA	3.5	a	26	64	67	56	53	31
		s	60	92	46	10	46	10
Clover size at spraying		a	1-2 tl	1-2tl	1-2tl	1-2tl		
		s	3-8tl	3-8tl	3-8tl	3-8tl		
No. of trials			4	4	6	6	6	6

a = October s = April tl = trifoliate leaves

WAT = weeks after treatment

TABLE 3

Treatments, dose (product/ha), timing and mean percent grass vigour

Treatment	l/ha	Timing	Mean % vigour 4WAT N	Mean % vigour 4WAT 2N	Mean % vigour May N	Mean % vigour May 2N
benazolin + 2,4-DB+MCPA	7	a	100	92	101	92
		s	98	91	98	91
CR 17139	5	a	98	98	101	96
		s	97	97	97	97
CR 17140	7	a	99	94	102	94
		s	99	92	99	92
bentazone +MCPB + MCPA	5	a	99	91	104	63
		s	98	95	98	95
bentazone + MCPB + MCPA	5	a	98	85	100	97
+ cyanazine	0.3	s	98	91	98	91
linuron + 2,4-DB + MCPA	3.5	a	87	69	90	70
		s	95	89	95	89
grass at spraying (ZCK)		a	15-22			
		s	24-30			
No. of Trials			7	7	7	7

a = October s = April

WAT = weeks after treatment

SWARD DESTRUCTION BY APPLICATION OF GLYPHOSATE BEFORE CUTTING OR GRAZING.

C D STRIDE, R V EDWARDS AND J C SEDDON

Monsanto plc, Thames Tower, Burleys Way, Leicester, LE1 3TP

ABSTRACT

A novel system has been developed to improve and simplify sward destruction with glyphosate whilst allowing maximum utilisation of forage and the minimum period for land to be unproductive.

Between 1980 and 1985, 21 small plot trials and 126 farmer trials were carried out and assessed up to one year from treatment.

Application of glyphosate between early June and late September before cutting or grazing of grass gave reliable weed control. Cutting of treated grass for conservation was possible 5 - 10 days after treatment. Forage quality was maintained from treatment, with no effect on palatability, feed acceptability or livestock health.

Large scale user trials indicated many realisable benefits and areas for future development.

INTRODUCTION

Glyphosate has proved effective for sward destruction post-harvest (Grossbard and Atkinson 1985) and showed perennial grass and broad-leaf species were more susceptible to glyphosate from early July to late August (Oswald 1976). Optimum dose rates were related to sward age and weed type, from 1.08kg ae/ha in short term swards containing Lolium multiflorum to 2.16kg ae/ha in permanent pastures infested with perennial broad-leaf weeds. This range of doses applied post-harvest of grass were found applicable to pre-harvest application.

Various constraints were inherent in the use of glyphosate post-harvest, including the need to wait 4 - 6 weeks for adequate weed re-growth. Livestock farmers were reluctant to destroy grass when forage was in short supply in a dry season as they needed to cut costs by maximising the production of high quality grass which has the lowest unit cost per unit of metabolizable energy (O'Keeffe 1982).

The application of glyphosate prior to cutting or grazing could surmount many restrictions associated with post-harvest treatment, such as weed growth stage, time between harvest and redrilling and wastage of green fodder.

A development programme was instigated in 1980, followed by registration and commercialisation in Spring 1985. This paper describes the timing of weed control in relation to harvest and the influence of glyphosate on forage conservation or grazing, fodder quality, livestock acceptability and animal health.

METHODS AND MATERIALS

Trials from 1980 - 1983 involved 21 small plot trials evaluating weed control, timing, harvest interval and forage quality following glyphosate treatment. In 1983 and 1984 126 user trials were carried out to evaluate weed control, feed acceptability, forage quality, grazing regimes and establishment of subsequent crops.

Glyphosate used in all trials was the isopropylamine salt of N(phosphonomethyl) glycine formulated as Roundup® herbicide and was applied up to 10 days before cutting in 200 l/ha and at a pressure of 2.0 bars using Van der Weij sprayer with Tee-jet 8002 nozzles.

Small plot trials had three replicates and a plot size of 10 - 50m².

In user trials, applications were made by farm sprayers to blocks of 2 - 4 ha, using doses of 1.08 - 2.20 kg ae/ha in 200 l/ha.

At application, growth stage of grass species varied from ear emergence up to seeds ripening prior to silage or hay respectively. In small plot trials, foliar kill of the sward was assessed 1, 2 and 4 weeks after treatment on a scale of 0-100 where '0' is no effect and '100' complete kill. In user trials, sward destruction was categorised into outstanding (95%+), commercially acceptable (80-95%) and poor (less than 80%).

Forage quality was evaluated on standard parameters; percent dry matter, percent crude protein, water soluble carbohydrates, metabolizable energy and 'D' value. With silage, pH and ammonia nitrogen levels were measured to ascertain fermentation quality. In total, 583 samples were taken from treated and untreated forage and evaluated independently. Forage samples were taken, 50, 100 and 150 days after baling or ensiling. Fresh grass samples were taken up to 18 days from treatment.

Palatability, feed acceptability and animal health studies were carried out at eight Universities, Colleges or Laboratories. Standard protocols were used to analyse palatability and acceptability of feed (Jones & Forbes 1984), digestibility of fodder (Alexander & McGowan 1966), rumen degradability (Paine et al 1981) and blood parameters (Reitman and Frankel 1957, Seelig & Wust 1969). Feeding studies in sheep, beef and dairy cattle compared animals fed treated or untreated fodder (Barber 1983).

RESULTS

Sward Destruction

Reliable control was obtained when the sward was treated at 27 - 80cm and cut 3 - 10 days afterwards. Interval between spraying and cutting had little influence on control of annual species but control of perennial species was reduced when swards were cut less than three days after treatment. The trends observed with applications made from early May to late September in a series of trials in long-term leys are shown in Table 1. Applications made prior to cutting from early June to late September gave 95 - 100% control of weeds. Application prior to June showed variable control with rapid elongation growth reducing susceptibility to glyphosate. Applications made pre-cutting to a range of species in three trials performed as well or better than post-harvest treatments applied 4 - 6 weeks after cutting, notably on broad-leaf species (Table 2).

TABLE 1

Effect of application date and plant height on control of grassland species by glyphosate at 1.8kg ae/ha on a 5 year ley infested with perennial weeds.

Date of Treatment in 1981	Crop Stage	Plant height (cm) & Mean Control (%) 1 MAT							
		Lolium perenne		Poa annua		Rumex obtusifolius		Ranunculus repens	
		Ht	%	Ht	%	Ht	%	Ht	%
8.5	Post-harvest	30	83	20	83	30	0	37	65
14.5	Post-harvest	35	40	21	40	30	95	38	80
22.5	Post-harvest	40	23	23	23	40	100	38	0
26.5	Post-harvest	45	68	28	68	52	100	40	0
1.6	Pre-cut grass	55	97	36	97	55	95	40	99
23.6	Post-harvest	8	97	5	97	18	0	8	0
30.6	Post-harvest	13	96	5	96	19	0	8	38
8.7	Post-harvest	23	97	5	97	20	100	8	100
14.7	Pre-graze	27	100	5	100	32	100	9	100
20.7	Pre-graze	29	100	8	100	35	100	12	100
27.7	Pre-graze	30	99	9	99	43	100	17	97
4.8	Pre-cut silage	42	99	18	99	46	100	20	100
10.8	Pre-cut silage	54	100	27	100	52	100	21	98
17.8	Pre-cut silage	58	100	27	100	55	100	23	100
26.8	Pre-cut silage	80	100	27	100	55	100	30	100
1.9	Pre-cut hay	80	100	27	100	74	100	30	100
9.9	Pre-cut hay	80	100	27	100	74	100	30	99
16.9	Pre-cut hay	80	100	27	100	74	100	30	100
28.9	Pre-cut hay	80	98	27	98	74	98	30	93

TABLE 2

Mean weed control (%) one month after treatment in three trials comparing application of 1.8 kg ae/ha glyphosate pre and post harvest

Timing of Treatment	Control of grass species (%)	Control of broad-leaved species (%)
Post-harvest - Spring	75	79
Pre-cut June - September	89	92
Post-harvest (3-6 weeks after cutting)	87	66

Grass species included: _Lolium perenne_, _Agrostis stolonifera_, _Dactylis glomerata_ _Holcus lanatus_ and _Festuca rubra_

Broad-leaf species included: _Rumex obtusifolius_, _Taraxacum officinale_, _Ranunculus repens_ and _Bellis perennis_.

Experience in 126 user trials in 1983-4 showed sward kill was greater than 85% in 94% of trials. In 23 trials assessed one year after treatment, 87% showed sward destruction at or above 90% (Table 3). Poorer control was observed with applications made in May to swards growing rapidly or which included Taraxacum officinale, Ranunculus repens and Trifolium repens. Good control of Festuca rubra was achieved at a dose of 1.8kg ae/ha glyphosate.

TABLE 3

Weed control (%) in various pastures in 23 farmer trials assessed one year after treatment.

Sward type	Glyphosate kg/ha	Principal weeds	Weed Control - % Numbers of trials 95-100	80-95	<80
Short leys 1-3 years old	1.08 - 1.44	Lolium spp Holcus lanatus Dactylis glomerata	2	5	1
Long leys 4-6 years old	1.44 - 1.88	Lolium spp, Rumex spp, Elymus repens Cirsium arvense	0	7	1
Permanent Pasture	1.80 - 2.16	Elymus repens, Festuca rubra, Cirsium arvense, Rumex spp, Agrostis stolonifera	3	3	1
Overall performance			5	15	3

Forage Quality

Glyphosate application stopped growth of all plants and caused gradual desiccation of forage. Dry matter increased by up to 7% in June and 15% in July in samples cut 7 - 10 days after treatment. A colour change was apparent after treatment with hay developing a pale bronze colouration and silage a yellow-green colouration.

Other parameters of forage quality were less affected by treatment with glyphosate prior to grazing, silage or hay (Table 4). Metabolizable energy, D-value and water soluble carbohydrate levels were maintained after treatment, whereas levels in untreated samples decreased.

Crude protein levels were similar in treated and untreated samples and silage fermentation was unaffected by glyphosate treatment and evaluation of forage quality in 9 user trials showed similar trends (Table 4).

The relative changes in quality over time are shown in Table 5, where over a ten day period in one trial, glyphosate treatment maintained forage quality and increased dry matter, compared to a decline in quality in untreated forage.

TABLE 4

Forage quality in small-plot and user trials comparing treated and untreated samples of grass, hay and silage.

Parameter	Grass for grazing (11 sample sets) Quality Assessments At Application	mean 10 DAT Untreated	mean 10 DAT Treated
Dry matter (%)	22.5	22.7	29.5
Crude protein (% DM)	15.4	12.3	11.8
'D' value	66.8	63.1	64.3
Metabolizable energy (MJ/kg)	10.7	10.1	10.3
Water soluble carbohydrates (%DM)	18.8	16.8	17.7

	Hay (11 sample sets) Untreated		Treated	
	Small Plot	User Trial	Small Plot	User Trial
Dry matter (%)	85.4	84.3	83.3	83.5
Crude protein (%DM)	10.9	9.7	9.9	10.8
'D' value	57.5	46.5	57.4	62.0
Metabolizable energy (MJ/kg)	8.6	8.8	8.6	9.1
	Silage (17 sample sets)			
Dry matter (%)	26.1	27.4	40.0	42.0
Crude protein (%DM)	13.9	12.4	13.5	13.0
'D' value	63.3	73.3	64.7	76.1
Water soluble carbohydrates (%DM)	2.9	8.0	6.7	10.5
Ammonia nitrogen (%DM)	7.4	1.4	7.0	1.2
pH	4.5	-	4.6	-

Samples of hay and silage were taken at a mean of 100 days after baling or ensiling.

The relative changes in quality over time are shown in Table 5, where over a ten day period in one trial, glyphosate treatment maintained forage quality and increased dry matter, compared to a decline in quality in untreated forage.

TABLE 5

Forage quality over 10 days after treatment with glyphosate.

Days after treatment DAT	Dry Matter %		Crude Protein % of D.M.		Water Soluble Carbohydrates		'D' value	
	TR	C	TR	C	TR	C	TR	C
0	22.8	22.8	11.0	11.0	29.9	29.9	71.0	71.0
3	23.4	24.8	9.1	7.2	30.1	32.1	70.0	69.0
10	33.2	25.9	8.6	8.5	29.2	27.7	70.0	66.0

TR = Treated C = Control (untreated)

Stock Acceptability

Results of tests carried out by Universities, Colleges and MAFF showed that fodder produced from grass treated with glyphosate had no adverse effects on animal health (Table 6).

Standard parameters including digestibility, liveweight gain, milk yield and quality, rumen degradability, blood parameters, live weight gain and birth weights were unaffected when sheep, beef or dairy cattle were fed treated forage when compared with untreated forage.

Stock showed no particular preference for treated or untreated forage. Large-scale trials showed very favourable results on acceptability and palatability of treated forage. Additionally, glyphosate treatment did not adversely affect digestibility or the handling of forage during conservation and feeding. Animals grazed treated swards normally from five to fourteen days after treatment.

TABLE 6

Stock acceptability and health studies.

Establishment	Stock	No. per treatment	Treated Crop	Feeding Period-days	Assessment
Universities					
Leeds	Wether sheep	6	Hay	49	Daily intake
North Wales	Fistulated bullocks	3	Hay	2	Rumen degrad-ability
Colleges					
Usk	Beef steers	8	Hay	21	Daily intake
Gloucester	Beef steers	3	Hay	56	Liveweight gain
Askham Bryan	Dairy Cows	50	Silage	14	Milk yield and quality
Harper Adams	Pregnant Ewes	10	Hay	21	Blood quality, live-weight gain, live births
M.A.F.F.					
Drayton EHF	Wether sheep	4	Hay	30	Digestibility
Great House EHF	Sheep	3	Hay	21	Digestibility and intake

DISCUSSION

Data presented from an extensive series of 21 small plot trials and 126 large-scale user trials over 5 years showed that glyphosate could be applied safely and effectively pre-cutting or grazing of grass, with no adverse effect on livestock when fed treated forage, and forage quality was maintained.

Through application to sward species at an optimum physiological growth stage, and to a large plant area, reliable weed control resulted, at least equal to that in post-harvest applications.

The trials highlighted several important benefits from applying glyphosate before cutting or grazing grass.

The application of glyphosate to a fully developed sward removes the need to wait for regrowth after cutting for the sward to reach a stage susceptible to glyphosate. Co-operators in the user trials obtained a minimum period from application to drilling the next crop of just 10 days, thus allowing rapid establishment of the following crop in a seed-bed free of perennial weeds.

The pre-cutting use of glyphosate, by fitting into farming practice, has allowed an extra cut of silage to be taken, thus permitting maximum utilisation of grass that is produced.

Areas for further development in the application of glyphosate pre-cutting in grassland include refinement of dose rates, maintaining 'D' value from application to conservation, direct cutting silage by dispensing with a wilting period, reducing time interval from cutting to baling hay and the reduction of transfer of pests, such as frit fly and aphids carrying Barley Yellow Dwarf virus.

ACKNOWLEDGEMENTS

The authors wish to thank the many farmers who co-operated in trials, the Nutrition Chemistry Laboratories of M.A.F.F. and other independent laboratories for their invaluable help in completing forage analyses and the Colleges and Universities who carried out the livestock feeding studies.

REFERENCES

Alexander, R.H.; McGowan, M. (1966) The routine determination of _in vitro_ digestibility of organic matter in forages - an investigation of the problems associated with continuous large scale operation. Journal of the _British Grassland Society_ _21_, 140 - 147.

Barber, D. (1983) Personal Communication.

Grossbard, E.; Atkinson, D. (1985) _The Herbicide Glyphosate_, Butterworths, London.

Jones, R.; Forbes, J.M. (1984) Effects of glyphosate and quinine on the palatability of hay for sheep. _Animal Production_ _38_, 301 - 303.

O'Keeffe, M.G. (1982) The role of herbicides in increasing energy yields from U.K. grassland. Proceedings of the _British Crop Protection Conference_ _1_, 357 - 361.

Oswald, A.K. (1976) The effects of seasonal applications of glyphosate on a mixed sward. Proceedings of the 13th British Weed Control Conference 3, 961 - 969.

Paine, C.A. et al (1981) Complete exchange method for the in sacro estimation of rumen degradability on a routine basis. Proc. BSAP/BGS. Symposium on forage protein in ruminant animal production. Leeds.

Reitman, S; Frankel, S. (1957) A colorimetric method for the determination of serum glutamic oxalacetic and glutamic pyruvic transaminases. American Journal Clinical Pathology 28, 56.

Seelig, N.P.; Wust. H (1969) Arztliche Laboratorium. Die Kreatinindestissunge Mit Der Jaffe-Reaktion, 15, 34

THE EFFECTS OF SULPHONYL-UREA HERBICIDES ON PTERIDIUM AQUILINUM (BRACKEN) IN HILL PASTURE

A.K. OSWALD, W.G. RICHARDSON

Long Ashton Research Station, Weed Research Division,
Begbroke Hill, Yarnton, Oxford OX5 1PF

C.E. FLINT

Agricultural Development and Advisory Service, Long Ashton Research Station,
Weed Research Division, Begbroke Hill, Yarnton, Oxford OX5 1PF

ABSTRACT

Sulphonyl-urea herbicide treatments were applied to Pteridium aquilinum at early and full frond emergence on five sites. Reductions of up to 100% in numbers and dry matter of fronds were recorded one year after treatment with chlorsulfuron alone and in mixture with metsulfuron-methyl, the latter being less effective when applied as a single treatment. Although there was found to be no overall difference in effects at the two stages of growth, frond height and target area are probably important factors in early applications. Grass dry matter production was not impaired even at the highest doses applied, when some significant increases were recorded. The standard treatment asulam achieved effective weed control but did not result in compensatory grass growth. This work confirms the earlier promise of sulphonyl-urea herbicides applied at extremely low rates of active ingredient to control P. aquilinum. However, the need for further long-term evaluation of dose and timing is stressed.

INTRODUCTION

It has been estimated that the annual national loss of hill grassland to P. aquilinum (L.) Kuhn (Bracken) in the UK is some 10,400 ha, out of a total of 3.5 m ha which is under threat of invasion (Taylor 1980).

Spraying with asulam has given good control but not eradication (Martin 1976, Veerasekaran et al. 1976, Williams and Fraser 1979) and many of the grasses associated with P. aquilinum have been shown to be susceptible (Soper 1970). Thus there was a need to find a herbicide which would provide successful, long-term weed control without damaging indigenous grasses.

Chlorsulfuron has given promising control of P. aquilinum with compensatory grass production and initial tests have suggested the potential of the more recently developed sulphonyl-urea, metsulfuron-methyl, alone and in mixture with chlorsulfuron (Oswald et al. 1985). Consequently, the Agricultural Development and Advisory Service established four experiments to investigate the efficacy of a commercially available formulation of chlorsulfuron and metsulfuron-methyl and metsulfuron-methyl alone (both currently used in weed control in cereals) applied at early and full frond emergence. The Weed Research Division of Long Ashton Research Station investigated the effects of chlorsulfuron and metsulfuron-methyl as single treatments and in mixture when applied at full frond emergence. Effects on numbers of fronds were measured on the five experiments with effects on frond and grass DM recorded at two of the sites.

MATERIALS AND METHODS

Details of the five experimental sites are shown in table 1.

The treatments shown in table 2 were applied at early and full frond emergence (experiments 1-3) and at full frond emergence only (experiments 4, 5). Each treatment was replicated three times in a randomised block design in plots 3 x 10 m (experiments 1, 2, 4) 2.5 x 10 m (experiment 3) and 3 x 5 m (experiment 5). An Oxford Precision Sprayer was used fitted with TeeJets No. 8003 (experiments 1-4) and 8002 (experiment 5) giving a volume of 200 and 300 l ha^{-1} respectively. On experiments 1-4 'Agral' as a 0.25% v/v solution was added to all sulphonyl-urea treatments, and as a 0.1% v/v solution to the asulam treatment. All vegetation was dry and no rain fell during any of the applications.

An area of 3 x 1 m^2 in the centre of each plot was divided into one metre quadrats and all P. aquilinum fronds present were counted. Harvests of P. aquilinum and grass were taken from the two outer quadrats (experiments 4 and 5) . All herbage was cut to ground level using hand shears after which the P. aquilinum and grass components were separated, weighed fresh, dried at 100°C for 16 h and re-weighed.

RESULTS

Effects on numbers of P. aquilinum fronds

All treatments caused significant reductions except some of the metsulfuron-methyl treatments applied alone. The less effective doses were 2.5 g ha^{-1} a.i. at both dates on experiments 1 and 3 and at full frond emergence on experiment 5, 5 g ha^{-1} a.i. at early frond emergence on experiment 3 and full frond emergence on experiment 5 and 10 g ha^{-1} a.i. at early frond emergence on experiment 3 (Table 2). Chlorsulfuron applied alone on experiment 5 was extremely effective at doses of 15 g ha^{-1} a.i. and above. On four of the experiments, the mixture of chlorsulfuron and metsulfuron-methyl applied at full frond emegence caused near eradication, even at the lowest dose combination applied. Asulam was also effective at all sites giving 56-98% reduction in numbers of fronds.

The mixture of chlorsulfuron and metsulfuron-methyl was more effective than metsulfuron-methyl alone when applied at early frond emergence at 2.5 g ha^{-1} a.i. (experiments 1, 2, 3, 5) and 10 g ha^{-1} a.i. (experiments 1, 3). Differences were also recorded following application at full frond emergence at 2.5 g ha^{-1} a.i. (experiments 1, 3, 5), 5 g ha^{-1} a.i. (experiment 5) and 10 g ha^{-1} a.i. (experiment 5). Values on experiment 4 were too low for accurate comparison. Chlorsulfuron alone was also more effective than metsulfuron-methyl at the doses applied on experiment 5.

There was no overall difference in the effects of spraying at the different stages of growth. However, the medium dose of metsulfuron-methyl on experiment 1, the high dose on experiment 3 and the low and medium doses of the mixture on experiment 1 were all more effective when applied at full frond emergence. A comparison of the results from experiments 1 and 2 with those from experiment 3 indicate that consistently better control was achieved from the early applications of low and medium doses of the mixture on the latter experiment suggesting the extent to which frond height and number of unfurled pinnae can affect the degree of control by providing a better spray target.

TABLE 1

Details of experiment sites, management and assessments

Experiment No.	1	2	3	4	5
Location	Marske, N. Yorks	Hurst Moor, N. Yorks	Fryup Dale, N. Yorks	Llanfrynach, Powys	Abergavenny, Gwent
Origin	ADAS	ADAS	ADAS	ADAS	LARS, WRD
Sward composition	*Agrostis* spp. *Festuca* spp. *Holcus* spp. *Poa* spp.	No grass	*Agrostis* spp. *Festuca* spp. *Holcus* spp.	*Agrostis* spp. *Anthoxanthum odoratum* *Holcus* spp. *Cynosurus cristatus* *Dactylis glomerata* *Juncus* spp.	*Agrostis capillaris* *Holcus mollis* *Anthox. odoratum* *Poa* spp. *Festuca ovina*
Date of spraying (stage A) Height of *P. aquilinum* (cm)	28 June 1984 15-25	28 June '84 15-25	4 July '84 30-45	-	-
Date of spraying (stage B) Height of *P. aquilinum* (cm)	9 Aug. 1984 -	9 Aug. '84 -	26 July '84 -	17 July 1984 -	18 July 1984 128 39 fronds m^{-2} 13 extended pinnae $frond^{-1}$
Height of grass (cm)	-	-	-	-	7.5, foliage dry
Assessment dates					
Frond counts	13 Aug. 1985	12 Aug. '85	12 Aug. '85	11 July 1985	18 July 1985
Frond and grass harvest	-	-	-	11 July 1985	18 July 1985

TABLE 2

The effect of sulphonyl-urea herbicides on the numbers of *Pteridium aquilinum* fronds m^{-2} 12 months after treatment at early (A) and full (B) frond emergence

Treatment	Dose (g ha^{-1} a.i.)	Timing	Experiment No. 1	2	3	4	5
1 Chlorsulfuron	7.5	B	-	-	-	-	13
2 "	15.0	B	-	-	-	-	4
3 "	30.0	B	-	-	-	-	1
4 Metsulfuron-methyl	2.5	A	47	45	12	-	-
5 "	5.0	A	28	35	9	-	-
6 "	10.0	A	20	20	12	-	-
7 "	2.5	B	55	50	15	3	20
8 "	5.0	B	7	45	8	1	21
9 "	10.0	B	14	18	3	1	7
10 Chlorsulfuron (7.5)+Metsulfuron-methyl(2.5)		A	32	30	2	-	-
11 " (15.0) " (5.0)		A	21	23	3	-	-
12 " (30.0) " (10.0)		A	2	6	1	-	-
13 " (7.5) " (2.5)		B	1	16	3	2	5
14 " (15.0) " (5.0)		B	1	29	2	1	2
15 " (30.0) " (10.0)		B	0	8	1	1	0
16 Asulam 4.48 kg ha^{-1} a.e.			1	4	3	4	2
17 Untreated control			56	72	17	9	27
		S.E.D. $\pm$	7.3	9.4	3.8	0.9	3.3

- = Treatment not applied

Effects on *P. aquilinum* frond DM

All treatments except the low dose of metsulfuron-methyl on experiments 4 and 5, caused significant reductions (Table 3). In experiment 5, chlorsulfuron reduced DM by 93 and 99% when applied at medium and high doses, while the high dose of metsulfuron-methyl reduced yield by 79%. The three doses of the mixture caused reductions of 92, 99 and 100% respectively. On experiment 4 the high dose of metsulfuron-methyl and all doses of the mixture reduced DM to undetectable levels. Asulam reduced yield by 100% at experiment 4 and 99% at experiment 5.

Effects on grass DM

Significant increases were recorded on experiment 5 following the low doses of chlorsulfuron and metsulfuron-methyl applied separately (83 and 90%) and on both experiments after the high dose of the mixture (79 and 100%) (Table 4). Slight increases following other sulphonyl-urea herbicides did not reach significance. Yields from asulam plots were the same as from untreated controls on both experiments.

TABLE 3

The effect of sulphonyl-urea herbicides on Pteridium aquilinum DM (g m^{-2}) 12 months after treatment at full frond emergence

Treatment	Dose (g ha^{-1} a.i.)	Experiment No. 4	5
1 Chlorsulfuron	7.5	-	138
2 "	15.0	-	30
3 "	30.0	-	2
4 Metsulfuron-methyl	2.5	47	348
5 " "	5.0	12	293
6 " "	10.0	0	92
7 Chlorsulfuron (7.5) + Metsulfuron-methyl (2.5)		0	34
8 " (15.0) " " (5.0)		0	5
9 " (30.0) " " (10.0)		0	1
10 Asulam 4.48 kg ha^{-1} a.e.		0	3
11 Untreated control		104	446
	S.E.D. ±	21.8	44.2

TABLE 4

The effect of sulphonyl-urea herbicides on grass DM (g m^{-2}) 12 months after treatment of Pteridium aquilinum at full frond emergence

Treatment	Dose (g ha^{-1} a.i.)	Experiment No. 4	5
1 Chlorsulfuron	7.5	-	104
2 "	15.0	-	71
3 "	30.0	-	70
4 Metsulfuron-methyl	2.5	23	108
5 " "	5.0	18	66
6 " "	10.0	20	69
7 Chlorsulfuron (7.5) + Metsulfuron-methyl (2.5)		18	83
8 " (15.0) " " (5.0)		28	75
9 " (30.0) " " (10.0)		34	114
10 Asulam 4.48 kg ha-1 a.e.		18	57
11 Untreated control		19	57
	S.E.D. ±	6.1	15.0

DISCUSSION

The results of this study confirm earlier work (Oswald *et al*. 1985) which indicated that chlorsulfuron at doses above 15 g ha^{-1} could give effective control of *P. aquilinum* without damaging grass. The effects of chlorsulfuron in mixture with metsulfuron-methyl also compared favourably with the level of control achieved by the standard asulam treatment with the suggestion that grass yields would not be impaired and may even be increased. Metsulfuron-methyl as a single treatment was not as effective as the mixture with chlorsulfuron or, at the doses applied, with the single application of chlorsulfuron on experiment 5. Increasing the dose might improve the level of weed control but this might also lead to unacceptable grass damage, as suggested in past studies (Oswald et al. 1985). Thus it appears that chlorsulfuron is the effective agent for P. aquilinum control in the mixture of the two sulphonyl-ureas.

Spray timing did not affect the overall degree of control achieved although it was feared that there was insufficient vegetation on two of the experiments for a satisfactory spray target at the early frond emergence stage. The initial results suggest that better contol may be achieved from early applications if fronds are in excess of 25 cm high and have several pinnae unfurled. This result is promising practically because the ability to spray early in the season is an advantage as ground applications can then be made with more safety.

The increases in grass DM following sulphonyl-urea treatments are noteworthy and suggest that there was no direct herbicide effect on the grass even at the highest doses applied. Effective removal of the weed canopy may also have resulted in compensatory grass growth. The similarity between grass yields on untreated plots and following asulam treatment in this study has also been recorded in previous work (Oswald et al. 1985). This suggests direct herbicide effect which would be supported by other work indicating the susceptibility of a number of grass species to asulam (Soper 1970).

Thus the sulphonyl-urea compounds applied at very low doses appear to have great potential for the control of P. aquilinum in hill pasture or amenity grass areas. However, it must be stressed that these are results obtained only one year after treatment and it is during the second year that more conclusive results are obtained, particularly on weed recovery. Nevertheless, these results are encouraging.

Future work is essential to confirm the promise of these chemicals. Many factors need to be resolved and initial studies should concentrate on the definition of which chemical or mixture of chemicals should be used, the optimum dose required and the best time to apply such a dose for effective control.

ACKNOWLEDGEMENTS

The authors thank the farmers for provision of land, DuPont (UK) Limited and May and Baker for chemicals and colleagues at Long Ashton Researh Station, Weed Research Division and the Agricultural Development and Advisory Service (at the Northern Region Leeds, Northallerton Area Office and ADAS Sub-Centre Cardiff) for assistance in the field and laboratory.

REFERENCES

Martin, D.J. (1976) Control of bracken. Botanical Journal of the Linnaean Society 73, 241-246.

Oswald, A.K.; Richardson, W.G.; West, T.M. (1985) The potential control of bracken by sulphonyl-urea herbicides. Bracken 85 International Conference on the Bracken Fern, University of Leeds (in press).

Soper, D. (1970) The tolerance of pasture grasses to asulam. Proceedings 10th British Weed Control Conference, pp. 465-475.

Taylor, J.A. (1980) Bracken: an increasing problem and a threat to health. Outlook on Agriculture 10, 298-304.

Veerasekaran, P.; Kirkwood, R.C.; Fletcher, W.W. (1976) The mode of action of asulam (methyl (4-amino-benzenesulphonyl) carbamate) in bracken. Botanical Journal of the Linnaean Society 73, 247-268.

Williams, G.H.; Fraser, D. (1978) The effects of asulam, frond cutting and ground mineral phosphate on the yield of swards dominated by bracken (Pteridium aquilinum (L.) Kuhn). Grass and Forage Science 34, 95-100.