INTRODUCTION

Weeds, Pests and Diseases in Grassland and Herbage Legumes — An Overview

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ABSTRACT

The importance of losses due to weeds, pests and diseases is considerable but not always obvious and, perhaps for this reason, such losses have attracted relatively little R & D. Both the problems and their solutions have to be seen in relation to the production systems to which they relate: this will generally require some kind of modelling. If weeds, pests and diseases frequently constitute a problem, it may be better to change the system than to deal with its consequences. In any event, solutions have to be selected that lead to economic benefits. Research and Development have to relate to the future and should thus be relevant to the probable production systems of the future. These may include novel systems involving new products or be characterised by lower inputs or orientation towards either conservation or human health.

The importance of losses due to weeds, pests and diseases of world crops is undeniable (Cramer 1967, GIFAP 1983), but those of grassland and herbage legumes have received relatively little attention. The position was summarised by Dibb (1981): although there was no consistent response to insecticide treatment on permanent pastures in the uplands (Clements 1979), pesticide treatment increased dry matter yield of perennial ryegrass by up to 32% (Henderson & Clements 1977) and losses of up to 20% DM can result from fungi and viruses in grass/clover swards (Carr 1979). A'Brook & Heard (1975) reported a reduction of 39% in yield of ryegrass plots infected with ryegrass mosaic virus. Insidious pest damage to white clover has been assessed by Clements & Henderson (1983) at between 8 and 11% reduction of DM yield, based on pesticide treatment of 26 varieties of 7 species of herbage legumes in 2 years. It is hard to quantify the research in this area, but, in relation to the area of grassland and to the value of its products, the volume of research and the scale of control measures appear slight.

The main reasons for the relatively small amount of work in this area are, presumably, that the effects are less evident – because of the nature of grassland

– and, indeed, to a considerable extent less easily quantified. This is partly because herbage is rarely the final product and partly because, as an intermediate product, it is not usually specified, except within quite a wide range of desirable characteristics.

Furthermore, since herbage quality is not measured during grazing, it is not usually possible to say whether it has been adversely affected by the presence of pests, weeds or disease. Indeed, the difficulties of quantifying the problem are considerable.

Assessment of the Problem

Weeds, pests and disease organisms are components of agricultural systems: where they are not, they can be ignored. This means (a) that their effect on the system as a whole has to be assessed, and (b) that changes made in response to their presence have to result in benefit to the whole system.

These rather obvious points can be illustrated as follows:

(a) No matter how great the damage to herbage or the reduction in quantity, resulting from weeds, pests or diseases, they cannot be regarded as serious problems if the output of the system (e.g. milk, meat, profit), measured over an adequate period of time, is not reduced as a consequence. Even if the physical output *is* reduced, of course, it does not follow that it will be economic to reduce the effects. This emphasises the fact that, ultimately, since grassland farming is an economic activity, the output or performance of the system has to be assessed in economic terms.

(b) Even if measures are taken that greatly reduce weed, pest or disease incidence, this reduction is not an adequate measure of benefit. If the system continues to give the same output or profit, after the measures are applied, as it did before, the measures cannot possibly be worthwhile.

Since both the statement of the problem and the examination of potential solutions require an adequate description of the system to which they are intended to relate, a degree of modelling is inevitably involved (Spedding 1979).

In developing countries, only simple models may be feasible, because of difficulties in quantifying relationships and great variation in time and space.

In developed agricultural systems, however, mathematical models ought to be of great benefit (Brockington 1979) and it is hard otherwise to see how the detailed knowledge of specialists can be brought to bear on such complex, multidisciplinary problems.

It is not merely, of course, that each pest, weed or disease has to be considered in relation to a described system, but they may interact significantly with each other. This not only complicates matters still further but makes it difficult to assess any one problem in isolation from others. It is quite possible for estimates of loss to involve double-counting if the estimated losses calculated for weeds, pests and diseases are simply added up. On the other hand, it is quite possible for one problem to exacerbate another, thus producing a greater total loss when several different deleterious organisms coincide.

As already indicated, if a systems approach is adopted, a weed, pest or disease organism can only be regarded as undesirable if its presence adversely affects the system output, performance or efficiency.

This carries with it the assumption that numbers and incidence influence the judgement but always *in relation* to a specific system.

Thus a weed may be an unwanted but harmless plant, an insect that can become a pest may not actually be so, and a disease-producing organism may simply not be having a serious effect at the time. When the organisms *are* undesirable in a particular system, it may be due to a combination of weather conditions, past and present, cultural practices and the proximity of other crops.

If they frequently constitute a problem in a given system, it follows that one option is to change the system. There is often reluctance to contemplate this and very high levels of input (and cost) can result from a single-minded pursuit of the solution of a problem, once it has arisen. Changing the system to prevent or avoid the occurrence of the problem is often regarded as retrograde when a new system is seen as representing marked progress (often because the view of the system is, in fact, over-simplified).

The ways in which husbandry systems may induce disease (for example, by the application of agrochemicals) has been reviewed by Hodges & Scofield (1983). They refer to 'agricologenic', or farmer-induced diseases as undesirable side effects of production systems, and their general theme is that the greater the interference with the agricultural ecosystem by increasing inputs of 'foreign' materials and intensive husbandry methods, the greater the tendency to generate agricologenic disease.

Solutions

The foregoing implies that, before seeking solutions, it is worth spending some time on stating the problems.

It is quite often the case that the reason why a problem remains unsolved is due to the way in which it is being stated. There are usually many different ways of doing this and some appear to be designed to encourage sympathy by making them look insoluble!

A simple example illustrates the point. A pest problem cannot be satisfactorily stated in the form of a simple question 'how to get rid of it'. It is bound to be recognised that what is meant is "how to get rid of it" in ways;

(a) that can be afforded;
(b) that do not kill the crops or livestock;
(c) that do not poison farmworkers or neighbours;
(d) that do not cause pollution, intolerable noise etc.;
(e) that result in improving output or performance of the system.

It should thus be clear that stating the problem in such a way that a satisfactory solution can be found is itself a considerable task. It is my contention that this is generally underestimated and insufficiently dealt with, partly because of the complexity of doing it well.

An adequate statement of the problem may involve an adequate description of the system in which it occurs and the same kind of model is needed to examine possible solutions.

It also follows that there are probably a great many possible solutions and it is rather inefficient to try them all out in practice in order to see which works best.

There are some ways in which possible solutions can be systematically sought (Spedding 1980; Conway 1983) and theoretically tested and it is worth considering them, in view of the obvious cost and difficulty of a trial-and-error approach to those 'solutions' that happen to occur to someone.

This is an important point because it avoids the frustrations of the research worker being forced to focus too sharply on an apparent problem and of the practical man confronted by a scientist who says that he has first got to learn a lot more about all the constituent parts of the system.

The facts are that it may be only by chance if a direct attack on a practical problem is successful, whilst, on the other hand, none of the scientists who examine the particular parts of the system that they are trained to look at (*i.e.* fall within their single discipline) may ever return to the original problem.

All this may appear rather general – and so it is, in the sense that it applies well outside the realms of weeds, pests and diseases – but it is particularly relevant to the interactive problems that occur in these categories. Amongst other things, it has a great bearing on the kind of R & D required.

The Need for R & D

Research is required for a number of different purposes: the more important can be listed as follows:

(a) to provide background knowledge of the non-crop organisms found in specified crop production systems, their life cycles and their interactions with each other and with crop species;
(b) to establish whether non-crop organisms cause significant reductions in the output or performance of the system, or, more precisely, in how many and what kind of years they do so;
(c) to explore changes in the system that might reduce incidence and damage;
(d) to examine possible solutions to problems, in a system context.

Even the first of these requires some multidisciplinary activity and cannot be entirely left to specialists operating in isolation. The other three categories (b, c and d) all require a knowledge of the whole system within which a problem occurs.

Indeed, as already argued, an organism cannot be described as a weed, a pest or a disease agent, except in relation to a specified system. Similarly, its economic importance has also to be related to the system in which it occurs.

This means that, since R & D has to be geared to the future, it is necessary to consider what systems of production are likely to be practised and on what scale.

The question of scale, like that of time, may be of great importance. Not only is it necessary to assess problems and find solutions in relation to the scale of the enterprise and the time for which it is carried out on the same land, it is also desirable to establish whether there are strong connections between these aspects and incidence or severity.

Although it is not possible to predict the production systems of the future, it is possible to discern some major possibilities; and one important activity for weed, pest and disease research workers is to try and foresee the likely problems associated with these options. In this way, research can influence the choice of option and not merely deal with the mitigation of problems after they have arisen.

Future Production Systems

1. Lower Input Systems

There are both economic and environmental reasons for considering low-cost production systems. The environmental interest is in the reduction in the quantity of 'artificial' inputs: the economic interest is in a reduction of the associated costs (see, for example, Hughes 1978). A reduction in output is not necessarily implied and, even where it occurs, the aim may be to sustain profit levels (though this is much affected by the level of overheads).

Since many of the inputs that may be reduced are concerned with the control of weeds, pests and diseases, the consequences of low input approaches may be considerable in relation to such problems. The implications for incidence, loss and control methods of operating low-input systems need to be worked out, therefore, in appropriate R & D programmes.

Of course, within this and any such category, there will be a great variety of different systems, each with its own characteristic problems, affected by the scale on which it is carried out and by the period over which it is continuously operated. Included in this category would be legume-based systems aimed at reduced inputs of fertiliser nitrogen.

2. Conservation-oriented Systems

It seems probable that some production systems will also be designed deliberately to foster conservation of wildlife. Such systems, or the environments in which they are operated, are likely to include features of importance to wildlife (hedges, copses, uncultivated areas of grass, ponds and lakes) and the systems themselves will include conservation practices. Some of the latter may be of the low-input kind but, even where inputs are high, it is still possible to avoid spraying the edges of fields and hedge-bottoms, for example (see Carter 1984).

This category represents a great opportunity because systems of this kind are currently being thought about. Their design could therefore be influenced, in the interests of week, pest and disease control. Biological control methods may find their greatest application in this category.

3. *Intensive Systems*

These may be little different from those in current practice but it is worth bearing in mind that some future systems may become *more* intensive, if only as a way of releasing land from Agriculture to all the other uses that presently compete.

For grassland systems, there is often an argument for intensive production in order to release as much land as possible for other crops.

4. *Systems Oriented Towards Human Health*

There appears to be increasing concern amongst people generally about the relationship between diet and health (Jollans 1983), and it would be unwise to assume that this has no relevance to grassland. Relationships between human health aspects of meat from grassland and the botanical composition and chemical treatment of the herbage may seem far-fetched but should not be ruled out just because the precise problem cannot currently be foreseen.

The most obvious current example is the public concern about nitrates in drinking water and the possible connection with past fertiliser practices. Concern of this kind might lead to changes in the amount, form or timing of fertiliser applications.

5. *Novel Production Systems*

New crops are occasionally introduced into UK agriculture and there are strong arguments for considering whether entirely novel crops and products exist as alternatives to current over-production. For grassland, however, it has become commonplace to regard the present methods of use as fairly fixed. 'Grass has no value until it is converted into animal products' has been a typical point of view. Novel uses have therefore generally been seen in terms of different animals, such as deer or rabbits, and there may still be possibilities in this direction that are worth exploring.

The fact that the UK imports virtually all of its fine wool seems odd when it could be produced here. The reasons for supposing that it could not are based on out-dated ideas about the Merino sheep and its ability to survive in the British climate (see Ryder 1973, and Boaz 1984) and the possibility of producing our own is not being seriously examined (not even theoretically, as a desk study or feasibility exercise).

Even less thought is given to the possibility of grassland and herbage legumes producing anything other than livestock products. Yet they may have constituents of medicinal value, or as enzymes, they might form a useful raw material for industrial processes, and they could be used as fuel crops (see Carruthers & Jones 1983).

Novel systems of these kinds may be the best answer to the problems of overproduction of food but some of them are not yet even devised and some of them are not yet economic.

The pest, weed and disease problems are likely to be quite different where the product is a specific plant constituent or where it is represented by the total biomass.

Green Crop Fractionation (Wilkins 1976) may yet find a place in UK grassland production, especially if it uses the fibrous fraction to fuel its own processing (McDougal 1980).

The Avoidance of Loss

The future may force a reduction in inputs, and thus of some control methods, but there will surely be good reason to avoid losses and wastage. Production may be lost after it has occurred or be reduced because resources and opportunities are wasted, due to pests, weeds and disease. It will surely be necessary to find ways of avoiding such losses that are economically and environmentally acceptable.

References

A'BROOK, J.; HEARD, A.J. (1975) The effect of ryegrass mosaic virus on the yield of perennial ryegrass swards. *Annals of Applied Biology* **80**, 163–168.

BOAZ, T.G. (1984) Merino sheep in Worcestershire. *The Ark* **11**(6), 172–174.

BROCKINGTON, N.R. (1979) *Computer Modelling in Agriculture:* Oxford University Press.

CARR, A.J.K. (1979) Causes of sward change: diseases. In: *Changes in Sward Composition and Productivity.* Occasional Symposium No. 10 British Grassland Society.

CARRUTHERS, S.P.; JONES, M.R. (1983) *Biofuel Production Strategies for UK Agriculture,* University of Reading, Centre for Agricultural Strategy: CAS Paper No. 13.

CARTER, E. (1984) Balancing economics and conservation. In: *Investing inRural Harmony: A Critique* (Ed A. Korbey) University of Reading, Centre for Agricultural Strategy: CAS Paper 16.

CLEMENTS, R.O. (1979) *Factors Affecting the Incidence of Stem-boring Diptera in Agricultural Grassland and Their Effect on Herbage Yield,* University of Reading: Unpublished Ph.D. thesis.

CLEMENTS, R.O.; HENDERSON, I.F. (1983) An assessment of insidious pest damage to 26 varieties of seven species of herbage legumes. *Crop Protection* **2**(4), 491–495.

CONWAY, G.R. (1983) *Agroecosystem Analysis,* London: Imperial College of Science & Technology Series E No. 1.

CRAMER, H.H. (1967) *Plant Protection and World Crop Production,* Leverkusen: 'Bayer' Pflanzenschutz.

DIBB, C. (1981) Technical factors affecting grassland output. In: *Grassland in the British Economy,* University of Reading, Centre for Agricultural Strategy: CAS Paper 10.

GIFAP (1983) *GIFAP Directory 1982–83,* Brussels: GIFAP (Groupement International des Associations Nationales de Fabricants de Produits Agrochimiques: Internation Group of National Associations of Agro-chemical Manufacturers).

HENDERSON, I.F.; CLEMENTS, R.O. (1977) Grass growth in different parts of England in relation to invertebrate numbers and pesticide treatment. *Journal of the British Grassland Society* **32**, 89–98.

HODGES, R.D.; SCOFIELD, A.M. (1983) Agricologenic disease. A review of the negative aspects of agricultural systems. *Biological Agriculture & Horticulture* **1**, 269–325.

HUGHES, H.C. (1978) *A Comparison of the Economics of Milk Production in Eire and Great Britain*, Thames Ditton: Milk Marketing Board LCP Information Unit Report No. 17.

JOLLANS, J.L. (1983) *Agriculture and Human Health*, University of Reading, Centre for Agricultural Strategy: CAS Paper 14.

MCDOUGALL, V.D. (1980) Support energy and Green Crop Fractionation in the UK. *Agricultural Systems* **5**(4), 251–266.

RYDER, M.L. (1973) Why *still* no merino sheep in Britain? *Wool Record*, 24 August 1973.

SPEDDING, C.R.W. (1979) *An Introduction to Agricultural Systems*, Barking: Applied Science Publishers.

SPEDDING, C.R.W. (1980) Prospects and limitations of operational research application in agriculture: agrobiological systems. In: *Operations Research in Agriculture and Water Resources*. (Eds D. Yaron and C.S. Tapeiro) 67–77. Amsterdam: North Holland.

WILKINS, R.J. (1976) (Ed) *Green Crop Fractionation*. Occasional Symposium No. 9 British Grassland Society.

PART 1

WEED PROBLEMS IN GRASSLAND ESTABLISHMENT

Occurrence, Impact and Control of Weeds in Newly Sown Leys

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ABSTRACT

This paper reviews the impact and damage caused by the major weeds, principally chickweed and annual meadow-grass, on grass and clover establishment. Early weed competition reduces tillering in grasses and restricts stolon development in clovers. Cultural control measures for preventing weed ingress are of limited value. Chemical control in all-grass leys is feasible and may be economically viable; economic thresholds need to be determined. Because of practical limitations of herbicide selection in clover-based leys (primarily lack of crop tolerance with autumn sowings), an alternative strategy is proposed involving establishing weed-free clover into which ryegrass is subsequently introduced.

Weed Occurrence

About 450,000 ha of grassland are sown annually. It is thought that just under half of this area is grass-after-arable, with a 40–60 split between spring (undersowing) and late summer sowings. Where grass is established in a mainly arable rotation, the most frequent weeds (Chancellor & Froud-Williams 1984) are likely to be weed grasses (rather than dicotyledonous weeds) notably common couch (*Elymus repens*), wild-oat (*Avena fatua*), black-grass (*Alopecurus myosuroides*), and meadow-grasses (*Poa* spp.). Of the dicotyledonous weeds, field pansy (*Viola arvensis*), cleavers (*Galium aparine*) and common chickweed(*Stellaria media*) occur most frequently, especially in autumn sown crops. In a survey of 95 newly sown grass fields in six counties (Haggar 1979a), chickweed was recorded as a problem on about 50% of the fields and annual meadow-grass on 37% of fields.

Reseeding old grassland produces a much more varied weed flora. For instance, in a survey of 9 fields in 1983, where the previous crop had been grass or root crops, a wide diversity of species were recorded, ranging from 8 to 28/site (R.J. Froud-Williams, unpublished data). The most frequently occurring species were meadow-grasses, chickweed, corn spurrey (*Spergula arvensis*), fat-hen (*Chenopodium album*) and shepherd's purse (*Capsella bursa-pastoris*). Further evidence of the diverse weed flora following the reseeding of old grassland has been obtained from a current national trial (A. Hopkins, unpublished data). The most common species, in priority order, were buttercups (*Ranunculus* spp.), creeping thistle (*Cirsium arvense*), annual meadow-grass, chickweed, dandelion (*Taraxacum officinale*), redshank (*Polygonum persicaria*), nettles (*Urtica dioica*) and sorrel (*Rumex acetosa*).

From these various sources, therefore, it may be concluded that grass weeds are most frequent in arable-grass sowings and that dicotyledonous weeds are most frequent in grass-grass sowings, with chickweed and annual meadow-grass being common to both types of sowings.

Weed Density

There is little information on the range of weed densities found in newly sown leys. In the above mentioned permanent pasture reseeding investigation, highest densities were recorded from annual meadow-grass, although values did not often exceed 100 plants m^{-2}, reflecting the large number of other weed species which were also present. On other sites, where annual meadow-grass was practically the only weed present, densities in the region of 10,000 plants m^{-2} (Younie *et al.* 1984), or even higher (Haggar & Kirkham 1981), have been recorded within 3 months from sowing, albeit reducing substantially thereafter through self-thinning.

Broad-leaved weeds, too, can sometimes occur at very high densities, e.g. 300 seedlings m^{-2} for fat-hen (R.J. Froud-Williams, unpublished data). By comparison, values of 12 and 25 for cleavers and chickweed, respectively are considered high in arable crops (B.J. Wilson, personal communication).

Damage Caused by Weeds

Early invading weeds adversely affect ley establishment and prejudice long-term productivity. In general, the presence of weeds complicates sward management decisions, lowers herbage quality, reduces sward utilization and hastens the onset of sward deterioration. Of particular concern is chickweed, especially when allowed to form large, smothering patches, which reduce grass tillering and clover establishment, at the same time as impeding mechanical harvesting and reducing silage quality. In one pot experiment, white clover plants were grown at two densities, 56 and 334 plants m^{-2}, in the presence and absence of three densities of chickweed (Table 1). White clover stolon length and nodes per plant proved particularly sensitive to chickweed competition, with virtually no stolons being produced at the highest weed density. There were also very significant reductions in number of leaves and total dry weight (e.g. there was over an 11-fold reduction in the mean number of leaves per plant). Weed damage was least where a high crop density was used.

Table 1: Effect of chickweed density on growth components of white clover grown at two densities

White clover components, plant $^{-1}$	Chickweed plants m^{-2} 0	56	168	336	s.e.	Clover seed rate Low	High	s.e.
Stolon, cm	25.2	5.9	1.0	0.2	2.7	11.6	3.9	2.4
Stolons	3.98	1.93	0.38	0.16	0.26	2.15	1.13	0.22
Nodes	15.5	4.7	0.7	0.2	1.4	7.7	3.0	1.2
Leaves	50.6	12.9	6.6	4.5	3.6	26.6	12.4	3.17
Shoot, g	1.32	0.29	0.13	0.48	0.11	0.63	0.24	0.10

One recent field experiment measured the effects of chickweed density on the establishment of an autumn sown grass/clover ley (S.P. Isaac, unpublished data). Perennial ryegrass cv. Talbot seed was sown on 6 September 1983 at either 5 or 25 kg ha^{-1}, with white clover cv. Grasslands Huia at 3 kg ha^{-1}. Various densities of chickweed (Table 2) were imposed. In March 1984, assessments of ground cover and tiller density showed that the grass ground cover had been halved by a chickweed density of 25 plants m^{-2} and that practically all clover plants had disappeared. White clover survival was encouraged by low seed rate of ryegrass, although this also encouraged chickweed growth. Thus, chickweed is a weed which can substantially affect ryegrass establishment and, particularly, prejudice long-term survival of white clover.

Table 2: Effect of chickweed density and grass seed rate on species components

Species	Chickweed plants m^{-2} 0	10	15	25	s.e.	Seed rate 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
Chickweed	0	39	50	61	5.6	42	33	3.9
Meadow-grass	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

Weed grasses, too, can impede crop establishment. For instance, in box experiments (Haggar 1979b) ryegrass tillering was reduced significantly by rough meadow-grass at densities commonly found in the field, with prior establishment causing disproportionate damage to ryegrass tillering. Other experiments have shown that rough meadow-grass can reduce ryegrass tillering by 20 to 30% during the first 6 weeks from emergence (Gibson & Courtney 1977). Similarly, annual meadow-grass hinders ryegrass tillering, especially when a low crop seed rate is used (Haggar & Passman 1978).

Mixtures of ryegrass and weed grasses may yield more DM in the short term than the crop monoculture (Wells and Haggar 1974). However, at levels above 25% ground cover, the yield contribution from the grass weeds is often insufficient, especially in dry seasons, to compensate for the reduced yield contribution of the sown variety (Aldrich & Camlin 1979). Even at more moderate levels of weed ingress, mis-management under farm conditions may cause a rapid increase in weed populations (especially with short-persistent crop varieties) and a lowering of total yields.

Preventing Weed Ingress

Cultural methods of preventing weed ingress in newly sown leys are limited. In a field experiment, doubling seed rates to 35 kg ha^{-1} only halved the yield of broad-leaved weeds and the inclusion of Italian ryegrass only caused a temporary check to seed ingress (Haggar 1979c); both approaches would have reduced clover establishment (Green & Corrall 1965).

With all-grass leys, a dense, vigorously growing crop is the best form of weed control. For example, Wells & Haggar (1984) showed that annual meadow-grass ingress into autumn sown perennial ryegrass was suppressed by broadcasting seed, rather than sowing in rows, and by using vigorous cultivars. Similarly, marked differences in weed susceptibility have been noted between ryegrass cultivars (Kirkham *et al.* 1982).

Plant growth regulators that encourage early tillering (e.g. products based on chlormequat) might prove useful, if they are combined with herbicides to reduce stimulation of associated weeds (Haggar & Reeves 1985).

Controlling Problem Broad-leaved Weeds in All-grass Leys

In all-grass leys, mixtures containing MCPA, mecoprop, dichlorprop, bromoxynil/ioxynil, dicamba and linuron, can be used, with due attention given to timing in relation to crop and weed growth stages (Haggar 1984). Of some concern, however, are field observations that mecoprop causes some damage to young grass plants. To check this point, four perennial ryegrass cultivars were sprayed at the two-leaf stage with mecoprop at 2.4 kg a.i. ha^{-1}. Results (Table 3) indicated that all cultivars were affected, notably Talbot.

Table 3: Effect of mecoprop on five ryegrass cultivars, harvested 5 weeks after spraying

Cultivar	Dry matter yield	Leaf nos.
	(as % of unsprayed)	
Antrim	81	106
Frances	98	95
Melle	82	92
Meltra	80	90
Talbot	76	81

Progress in Controlling Weed Grasses

Indigenous grasses can be selectively controlled in young ryegrass leys, based on early applications of methabenzthiazuron (Blair, 1970; Kirkham, 1981) and ethofumesate (Blair 1972; Griffiths & Hammond 1979). The former herbicide was shown to be safe to use pre-emergence in spring barley undersown with ryegrass, whilst the latter had the potential of controlling a wide range of weed grasses (Haggar & Bastian 1976). Field experiments have shown that both these herbicides control annual meadow-grass (and chickweed) in autumn sown leys with consequent benefit to crop establishment and short-term herbage production (Haggar & Kirkham 1981). Early spraying was found to be most effective, provided that the ryegrass seed was covered and that soil conditions were appropriate (Haggar & Passman 1981). A third herbicide, metamitron, was found to have a similar range of selectivities (Kirkham & Richardson 1981). These herbicides, plus mecoprop, were compared in various mixtures and sequences to prolong activity and reduce costs; the results emphasised the importance of controlling both annual meadow-grass and chickweed before full benefits can be reaped (Kirkham & Haggar 1982).

None of these herbicides are safe on swards containing clover. Prospects of finding a herbicide to control both weed grasses and chickweed in young grass/clover leys are not high (Kirkham 1983; Kirkham & Richardson 1983).

An alternative approach to selectively controlling weeds in seedling grass-clover leys is to use sequential applications of low-dose paraquat on ryegrass cultivars bred specifically for tolerance to paraquat. Field experiments had demonstrated that paraquat at about 0.2 kg a.i. ha^{-1} is strongly selective between perennial ryegrass cv. Causeway and other grasses or broad-leaved weeds (Faulkner 1978; Kirkham 1980). Differences in paraquat tolerance have also been demonstrated among white clover varieties (Faulkner 1980); Pronitro is the most appropriate variety to sow with paraquat tolerant ryegrass for long-term leys.

Economics of Seedling Weed Control in All-grass Leys

Doyle & Elliott (1983) have assessed the likely economic benefits of controlling weeds in young leys. Using data from a field experiment (Haggar & Kirkham 1981) they assumed that chickweed had no economic value, while annual meadow-grass and perennial ryegrass were both valued at 3.5 pence kg^{-1} DM. Their calculations showed a favourable comparison between the estimated rate of return, compared with observed returns from alternative investment. They concluded that if the yield data were typical of practical farming situations then the seedbed treatment of grass leys with ethofumesate would be an economically attractive proposition. However, a wider range of weed density/yield reduction relationships are needed before more precise economic analyses can be worked out.

Even in cereals, precise *economic thresholds* (densities at which the cost of herbicide treatment is offset by the increased value of the crop) are bedevilled by large variations between and within fields (B.J. Wilson, personal communication). Moreover, spraying weed populations lower than the economic threshold may be justified to minimise seed returns to succeeding crops.

Table 4: Spray decision rules in cereals

	High	Economic threshold	Don't spray	(Weed equivalent)
		(plants m^{-2})		
Wild oats	12	8–10	2– 3	(1)
Black-grass	70	30–50	5–10	(5)
Meadow-grass	250	100–200	20–40	(25)
Cleavers	12	2– 4	1	(2–3)
Chickweed	25	8–10	2–3	(2)

Table 4 summarizes current thinking on decision rules for controlling weeds in arable crops. It is presented as a basis for deriving similar guidelines for grass leys. The weed equivalent values indicate that wild oats are 4–5 times more competitive than black-grass. Less is known about the relative competitive ability of broad-leaved weeds; a first attempt suggests that cleavers are about three times more damaging than chickweed. Obviously, these data refer to competitive effects in tall growing cereal. Comparable information is needed for the more prostrate and denser canopies of newly sown grass/clover leys.

Elusive Clover Establishment

Although most seed mixtures contain white clover, surveys and field experiences have highlighted: (a) the variable success in establishing clover under practical farming conditions with chickweed being a key factor, especially in autumn sown leys, and (b) the long time it can take for white clover to build up to a meaningful presence.

Controlling broad-leaved weeds in cereal crops undersown with white clover is not a problem (Broughton *et al.* 1982). With late-summer sowings, however, clover seedlings are often too small and vulnerable for spraying in early autumn. On the other hand, delaying spraying into late autumn is risky due to lowering temperatures causing a reduction in crop tolerance. This is of particular concern with those herbicide mixtures which are near the limit of their selectivity. For instance, Kirkham *et al.* (1984) reported that whereas mixtures containing either bentazone, benazolin, MCPB, 2, 4-DB and MCPA controlled a wide range of weeds, they were certainly damaging to white clover establishment and long term survival.

Targets for white clover establishment have not been calculated. (About 150 plants m^{-2} 12 weeks after sowing seems sensible, translating to 30% ground cover about 12 months later.) There is also a lack of suitable assessment techniques for judging success or failure in clover establishment and long term survival. It is therefore not surprising that claims of 'clover-safety' have been made, based perhaps on the presence of a few clover plants a few months after spraying. Although such plants might be survivors of the original population, they could also be volunteer plants arising from viable seed in the soil. Before true crop safety can be claimed, it is essential to monitor treated plants under weed-free conditions. Preliminary research, involving monocultures of white clover grown in pots and the field, has indicated that spraying at recommended growth stages and doses can drasticallly reduce crop vigour and even population density (Standell 1985).

Because of these practical difficulties an alternative strategy is proposed. White clover could be established first, either undersown (e.g. in peas) or sown alone, with pre-emergence weeds being controlled by EPTC and post-emergence weeds being killed with MCPB/benazolin/bentazone mixtures. By late summer the clover crop would be strongly established and could be slot-seeded with ryegrass. Such a regime would result in effective clover establishment and the rapid production of a well balanced ley.

References

ALDRICH, D.T.A.; CAMLIN, M.S. (1979) Experience of changes in sward composition and productivity from evaluation of species and varieties. *Proceedings British Grassland Society Occasional Symposium number 10*, 85–91.

BLAIR, A.M. (1970) Herbicides for control of grass weeds when establishing ryegrass. *10th British Weed Control Conference*, 495–499.

BLAIR, A.M. (1972) Selectivity of NC 8438 between ryegrass and weed grass species. *11th British Weed Control Conference*, 301–305.

BOUGHTON, D.N.; WOODCOCK, P.M.; COOPER, F.B.; JOHNSON, J. (1982) Broad-leaved weed control and clover safety of bentazone mixtures used in undersown cereals and direct-sown leys. *British Crop Protection Conference – Weeds, 1982* 363–367.

CHANCELLOR, R.J.; FROUD-WILLIAMS, R.J. (1984) A second survey of cereal weeds in central southern England. *Weed Research*, **24**, 29–36.

DOYLE, C.J.; ELLIOTT, J.G. (1983) Putting an economic value on increases in grass production. *Grass and Forage Science*, **38**, 169–177.

FAULKNER, J.S. (1978) The use of paraquat for controlling weeds in seedling swards of paraquat resistant *Lolium perenne* L. *1978 British Crop Protection Conference – Weeds*, 349–355.

FAULKNER, J.S. (1980) Variations in paraquat tolerance in seedlings of *Trifolium repens*. *Record of Agricultural Research (Department of Agriculture for Northern Ireland)*, **28**, 27–31.

GIBSON, D.I.; COURTNEY, A.D. (1977) Effects of *Poa trivialis*, *Stellaria media* and *Rumex obtusifolius* on the growth of *Lolium perenne* in the glasshouse. *Annals of Applied Biology*, **86**, 105–110.

GREEN, J.O.; CORRALL, A.J. (1965) The testing of grass varieties in swards with clover: the effect of grass seed rate on comparisons of grass yield. *Journal of the British Grassland Society*, **20**, 207–211.

GRIFFITHS, N.; HAMMOND, C.H. (1979) Establishing weed free swards. *Proceedings British Grassland Society Occasional Symposium number 10*, 191·197.

HAGGAR, R.J. (1979a) *Grass Reseeding Survey 1977–78*. pp. 13. Hurley: British Grassland Society.

HAGGAR, R.J. (1979b) Competition between *Lolium perenne* and *Poa trivialis* during establishment. *Grass and Forage Science*, **1**, 27–36.

HAGGAR, R.J. (1979c) The influence of herbicides, nitrogen fertilizer, seed rate and method of sowing on the establishment and long-term composition of a perennial ryegrass ley. *Weed Research*, **19**, 1–9.

HAGGAR, R.J. (1984) The establishment phase. In: *Crop Protection Handbook – Grass and Clover Swards*, (Ed R.D. Williams) 17–29. Croydon: British Crop Protection Council.

HAGGAR, R.J.; BASTIAN, C.J. (1976) Controlling weed grasses in ryegrass by ethofumesate with special reference to *Poa annua*. *1976 British Weed Control Conference*, 603–607.

HAGGAR, R.J.; KIRKHAM, F.W. (1981) Selective herbicides for establishing weed-free grass 1. Evaluation of ethofumesate and methabenzthiazuron. *Weed Research*, **21**, 141–151.

HAGGAR, R.J.; PASSMAN, A. (1978) Benefits of controlling *Poa annua* in newly sown ryegrass leys. *1978 British Crop Protection Conference – Weeds*, 301–308.

HAGGAR, R.J.; PASSMAN, A. (1981) Soil persistence and distribution of ethofumesate applied to autumn-sown perennial ryegrass for *Poa annua* control. *Weed Research*, **21**, 153–159.

HAGGAR, R.J.; REEVES, R.A. (1985) Evaluation of Agrispon and Tillermor on the establishment and yield of a grass/clover sward. *Annals of Applied Biology* (in press).

KIRKHAM, F.W. (1980) Weed control by paraquat during the establishment of paraquat-resistant ryegrass. *British Crop Protection Conference – Weeds, 1980* 477–482.

KIRKHAM, F.W. (1981) The effect of pre- and post-emergence spraying with methabenzthiazuron on the herbage production of six ryegrass cultivars. *Annals of Applied Biology, 97*, Supplement, TAC **2**, 54–55.

KIRKHAM, F.W. (1983) The potential of various herbicides for selective weed control of weed grasses and *Stellaria media* in newly sown ryegrass/clover leys and ryegrass seed crops. *Technical Report Agricultural Research Council Weed Research Organization*, **70**, pp.13.

KIRKHAM, F.W.; HAGGAR, R.J. (1982) Selective herbicides for weed-free grass. The effects of mixtures and sequences of herbicides, including ethofumesate and methabenzthiazuron. *Weed Research*, **22**, 57–68.

KIRKHAM, F.W.; RICHARDSON, W.G. (1981) The pre-emergence selectivity of 12 herbicides between ryegrass, white clover and four grass-weed species. *Annals of Applied Biology, 97,* Supplement, TAC **2**, 46–47.

KIRKHAM, F.W.; RICHARDSON, W.G. (1983) The post-emergence selectivity of 14 herbicides between perennial ryegrass, white clover and four grass-weed species. *Annals of Applied Bology, 102,* Supplement, TAC **4**, 100–101.

KIRKHAM, F.W.; HAGGAR, R.J.; ELLIOTT, J.G. (1982) Controlling weeds during grass establishment. *Ninth Report, Weed Research Organization,* 55–61.

KIRKHAM, F.W.; HAGGAR, R.J.; BIRNIE, J.E. (1984) Late autumn control of chickweed in newly-sown ryegrass/white clover leys. *Proceedings British Grassland Society Occasional Symposium number 16*, 48–51.

STANDELL, C.J. (1985) The tolerance of four forage legumes to several herbicides. Proceedings BCPC/BGS Symposium on *Weeds, Pests and Diseases of Grassland and Herbage Legumes,* Nottingham, April 1985, 286–287.

WELLS, G.J.; HAGGAR, R.J. (1974) Herbage yields of ryegrass swards invaded by *Poa* species. *Journal of the British Grassland Society,* **29**, 109–110.

WELLS, G.J.; HAGGAR, R.J. (1984) The ingress of *Poa annua* into perennial ryegrass swards. *Grass and Forage Science,* **39**, 297–303.

YOUNIE, D.; WILSON, J.F.; CARR, G. (1984) Effects of application strategy of ethofumestate on control of annual meadow grass in young ryegrass swards *Annals of Applied Biology, 104,* Supplement, TAC **5**, 76–77.

The Control of Weed Populations during Grass Establishment by the Manipulation of Seed Rates

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ABSTRACT

For the establishment of amenity grass turf very high seed rates (>25 g m^{-2}) are commonly recommended, and are justified partly on the basis of improved weed control. However, results from experiments at Monks Wood suggest that the weed control achieved by using these high rates are slight and that other factors such as choice of species have a much greater influence. But at the much lower seed rates used to establish agricultural grassland the effect of seed rate may be more pronounced. In an experiment on spring sown ryegrass swards using 7 seed rates (ranging from .5 g m^{-2} to 32 g m^{-2}) there was a decline in weed from 38% to 7% of total yield as seed rate increased from .5 g m^{-2} to 8 g m^{-2}. A further increase in seed rates to 32 g m^{-2} had little more effect.

These data are used as a basis for discussing the extent to which inter-specific competition acting on weed seed germination, on weed seedling mortality and on weed seedling growth, may be manipulated to control weed establishment in grassland.

Introduction

A knowledge of the effects of plant competition is fundamental to a discussion on weeds and crop production. Although damaging effects of increasing weed densities on crop yield are well documented (Snaydon 1982) the reciprocal effects of increasing crop density on weeds are less well known. The effects of competition mean that not only do increasing weed densities decrease crop yields but also that increasing crop densities reduce weeds. In his review of weed-crop competition Zimdahl (1980) cited 9 examples of these effects in arable crops but none from grassland. Although it is likely that an increase in grass seed rates would, through the process of inter-specific competition lead to a suppression of weed populations, information on the magnitude of this effect and its possible relevance to grassland weed control is lacking.

The effects of competition are already exploited in the establishment of amenity grass turf, where the use of high seed rates (>25 g m^{-2}) are partly justified in terms of improved weed control (Beard 1973). However the actual degree of control is rarely quantified and recent work suggests that after one year the beneficial effects are slight, with, for example, a sixty-four fold decrease in seed rate of ryegrass resulting in only a four fold increase in weeds (Parr 1984).

This paper presents a summary of results from experiments on turf establishment which further demonstrates the effects of increasing seed rate on weeds. Although these experiments were done within the framework of an amenity grass research programme, the range of seed rates used was sufficiently wide for the results to have some relevance to agricultural conditions. Certainly, the ecological principles pertaining to competition and weed control are common to both amenity and agriculture and so through this avenue the extent to which weed control in grasslands may be achieved by manipulating grass seed rates is explored.

Materials and Methods

Data are presented from two experiments done at Monks Wood Experimental Station, Cambridgeshire, on a heavy clay soil with a pH of about 6.5. In both cases the effects of grass seed rates on indigenous weed populations were investigated.

EXPERIMENT 1 — EFFECTS OF RYEGRASS SEED RATE ON WEED GROWTH

This experiment was sown in May 1981 with 8 different seed rates of ryegrass (*Lolium perenne* S.23 at 0, .5, 1, 2, 4, 8, 16, 32 g m^{-2}) and 3 nitrogen fertilizer rates (0, 50, 200 kg N ha^{-1} $annum^{-1}$). Further experimental details are given in Parr (1984).

Dry matter yields of ryegrass and all other species were determined from cuttings taken from all plots. Biomass remaining as stubble was also determined for seed rates of 32 g m^{-2} and 4 g m^{-2}.

Results are presented for those plots cut at 44 mm, 14 weeks after sowing.

EXPERIMENT 2 — EFFECTS OF GRASS SPECIES ON WEED GROWTH

This experiment was sown in September 1983 incorporating 5 grass species (*L. perenne* S.23, *Phleum pratense* S.48, *Festuca rubra* ssp. *commutata* Barfalla, *Poa pratensis* Baron, *Agrostis castellana* Highland) treated with either 0 or 250 kg N ha^{-1}.

The plots were mown at 32 mm every two weeks between 27 April 1983 and 18 July 1983 and cuttings were subsampled for dry matter determinations of sown grass and unsown species. Dry matter of turf and weeds below cutting height was also determined in September 1983.

Results from only two of the four seed rates used (20 and 2.5 g m^{-2}) are given here.

Results

Effect of Ryegrass Seed Rate on Weed Yield

There were 24 weed species recorded in experiment 1 (Table 1) of which one, *Rumex obtusifolius*, regenerated vegetatively and the remainder were derived from the existing seed bank. All species showed high spatial variability and hence seed rate effects were demonstrated most clearly in terms of total weed yield.

The total yield of ryegrass in the herbage harvested (Fig. 1a) was independent of ryegrass seed rates of between .5 and 32 $g\ m^{-2}$ ($P>.05$). However, the percentage of weeds declined from 38% (±4.5) at the lowest seed rate to 7% at a seed rate of 8 $g\ m^{-2}$. Between 8 $g\ m^{-2}$ and 32 $g\ m^{-2}$ weeds formed a constant, 6%, of the total biomass.

The percentage of weeds in the stubble was 44% less than that removed in herbage (Fig. 1b), but the trends in relation to seed rate were similar. At a seed rate of 32 $g\ m^{-2}$ the percentage of weeds in the stubble was 1.3% (±.5) whereas at the rate of 4 $g\ m^{-2}$ this increased to 7.5% (±1.9).

Table 1: Yields ($g\ m^{-2}$) of ryegrass and main weed species in relation to nitrogen treatment (averaged over 8 seed rates). ± Standard error of means

Nitrogen kg ha^{-1} $annum^{-1}$	0	50	200
Rumex obtusifolius	29.4	4.9	16.3
Polygonum aviculare	3.4	4.6	10.7
Tripleurospermum maritimum	2.2	3.8	7.6
Sonchus oleraceus	.5	4.2	1.9
Chenopodium polyspermum	.2	3.0	3.4
Polygonum persicaria	2.4	.1	.2
Ranunculus repens	.4	.5	1.5
Senecio vulgaris	.1	1.5	.7
Total weeds (24 species)	39.9 ± 10.8	24.4 ± 10.8	44.3 ± 10.8
Ryegrass	79.9 ± 10.5	87.3 ± 10.8	176.3 ± 10.5

As weed (W) yields increased at low seed rates there was a corresponding decrease in ryegrass (R) yields (Fig. 1a) described by the inverse linear relationship, $R = 177 - 1.74\ W$ ($r = .96$, $P<.01$). However, the lack of a control with no weeds made it impossible to deduce whether declining ryegrass yields were due to increased weed populations or lower seed rates.

In contrast, the competitive effects of ryegrass on weed yields were clearly demonstrated with increasing ryegrass seed rates of up to 8 g m^{-2} causing significant reductions. Weed yields as a proportion of weed yields in the control plots (with no ryegrass) showed a negative exponential relationship (Fig. 2a) with a lower asymptote of 17% reached at seed rates over 8 g m^{-2}. This relationship was independent of levels of nitrogen fertilizer.

Effect of Different Species

Comparisons between the 5 species used in experiment 2 showed a wide difference in the susceptibility of turf from different species to weed growth (Table 2). The percentage of weeds (in herbage harvested and standing turf biomass) varied from 2 to 39%, with the order of effectiveness of weed control being *L. perenne* > *Agrostis castellana* > *Phleum pratense* > *Festuca rubra* > *Poa pratensis*.

All species showed improved weed control at the higher seed rate of 20 g m^{-2}, although with no nitrogen added this effect was only significant in ryegrass. On average, the eight fold increase in seed rate led to a 46% decline in weeds with no nitrogen and a 59% decline at the high nitrogen level.

The addition of 200 kg N ha^{-1} had no effect on the absolute biomass of weeds but because of the increased grass yields the proportion of weeds declined from 16 to 7% at seed rates of 20 g m^{-2} and from 27 to 15% at the lower rate of 2.5 mg m^{-2}.

Table 2: Total dry weight of weeds (g m^{-2}) and proportion of weeds (bracketed) in relation to nitrogen, seed rate and grass species

	0 kg N ha^{-1}		200 kg N ha^{-1}		
Seed rate	2.5 g m^{-2}	20 g m^{-2}	2.5 g m^{-2}	20 g m^{-2}	Mean
Lolium perenne	18.1* (.051)	1.1+(.002)	24.2* (.030)	4.9 (.006)	12.1 (.022)
Phleum pratense	49.1 (.181)	29.8 (.104)	55.0* (.086)	20.1 (.039)	38.5 (.102)
Festuca rubra	110.2 (.445)	45.2 (.219)	141.3* (.263)	48.5 (.078)	86.3 (.251)
Poa pratensis	126.1 (.594)	82.1 (.420)	150.9 (.346)	81.9 (.210)	110.2 (.393)
Agrostis castellana	20.5 (.069)	16.1 (.051)	22.4* (.028)	7.2 (.011)	16.5 (.040)
Mean of all species	64.8* (.268)	34.9 (.159)	78.8* (.151)	32.5 (.069)	

Significant differences ($P<.05$) for comparisons within species (from analyses of variance of log transformed weights) shown by * for differences in effect of seed rate at same N level and by + for differences in effect of N level at same seed rate.

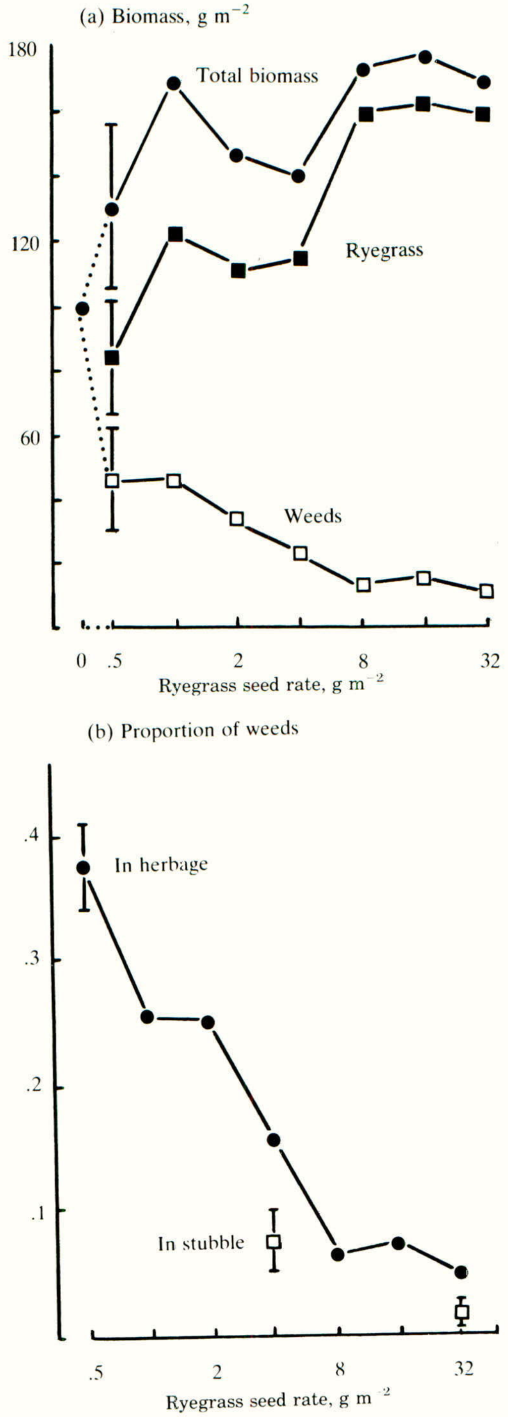

Figure 1: Effect of ryegrass seed rate on components of biomass in herbage

Weed control in these different species was related to the early production of grass biomass, in this case measured by grass biomass achieved after the first 10 weeks of growth in autumn. The curve of weeds (fraction of control) against sward biomass (Fig. 2b) showed a similar negative exponential relationship to that for ryegrass seed rates (Fig. 2a) with a rapid decline in weeds at low sward biomass (equivalent to low seed rates of *Lolium*) towards a lower asymptote of 8% weeds.

Discussion

These results suggest that the relationship between weed yield (measured as a fraction of controls) and seed rate of grass follows a negative exponential with a lower asymptote such that for ryegrass little additional weed control is achieved above a seed rate of 8 g m^{-2}.

This empirical result begs a number of ecological and practical questions. First, what factors are responsible for controlling weed yields and second, what influences the level of the lower asymptote of weeds and is it possible for this level to be negligible or zero without recourse to using herbicides.

Competition between grass and weed growth may lead to a suppression of weed biomass during establishment in three ways. First, though suppression of weed seed germination, second through decreased weed growth rates and a reduction of plant size, and third, through increased weed plant mortality.

Competitive effects on Weed Germination

Seed germination may be inhibited by a competitor species, either by the effects of allelopathic substances acting as germination inhibitors, or by indirect influences through changes to the local environment, such as light quality or soil water depletion (Linhart 1976). Allelopathic effects have been difficult to identify in the field but an extreme example of the second mechanism is shown by the failure of autumn germinating weed seeds to germinate under the canopy of a spring sown pasture. This effect may occur in the short term if a grass sward develops quickly enough and may be encouraged by using high seed rates. However, this is unlikely to have been an important factor in weed control in the experiments described above.

Competitive Effects on Weed Growth

The growth of crops and weeds is usually a mutually exclusive process (Hawton 1980) and the outcome of competition during the establishment year is largely determined by the rate at which species can pre-empt space and the resources it contains (e.g. water and nutrients). Hence, for individuals, competitive success is characterised by rapid germination, large initial seedling size and high initial growth rates (Harper 1977). At the population level, competitive effects may be enhanced by high population densities. Hence, the rapid decline in weeds in

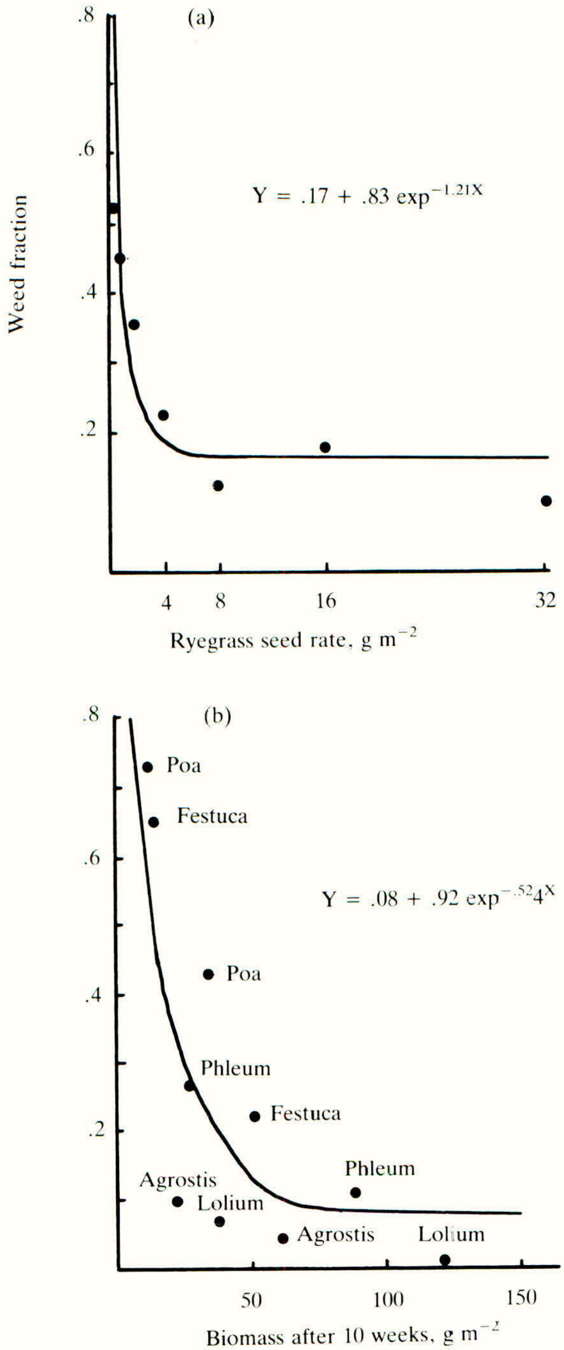

Figure 2: Relationships between weeds (fraction of controls and a) ryegrass seed rate in experiment 1; b) biomass of grass after 10 weeds of experiment 2

response to increasing ryegrass seed rates is due both to the innate competitive ability of each ryegrass plant, which enables it to occupy space quickly, multiplied by the ryegrass population density. This second factor is directly proportional to seed rate.

A large population of small individuals may be as competitive as a small population of large individuals. In the experiment described here ryegrass seedlings were, after 24 d, 9 times bigger than those of *Agrostis castellana* and yet because of the much higher population densities of *A. castellana*, both species were effective in preventing weed growth. Their superiority over *Festuca rubra* and *Poa pratensis* was on account of their more rapid germination and higher early growth rates.

Competitive Effects on Weed Plant Mortality

Plant mortality is usually size dependent (White 1980) and therefore the decreased growth rates of weeds under competitive stress are likely to lead to increased mortality. Mortality is usually due to lack of light and becomes more severe as the sward canopy develops, but since it is usually the small individuals which succumb, this natural mortality is unlikely to be a major influence on final weed yields during establishment but may have a greater influence on the long term species composition of the sward.

It seems unlikley that these three factors acting alone, or in concert, will through medium of high seed rates achieve total weed control. This is probably because for a short time after sowing, and before seedling establishment, there is a period which is competition-free and during which the space occupied by weeds is irretrievably held. This is the reason why early weed control is so generally advocated (e.g. Haggar 1979). Increased seed rates will not help achieve control during this period, but other factors such as rapid germination and early grass growth, as shown by the performance of difference grass species in the experiment reported here, are likely to be important.

The effects of seed rate on weed growth are likely to be modified by cultural factors such as cutting regime and fertilizers. For instance, cutting removes a proportionately greater quantity of weeds, particularly annuals, than grass and therefore tends to lower the proportion of weeds left in the stubble. Similarly, pasture grasses are more efficient at exploiting added fertilizers and therefore the proportion of weeds in the sward declines as nitrogen levels increase (Parr 1984). But the indication from the results of the experiments described in this paper is that there is no interaction between the effects of seed rate and other cultural factors and that seed rate effects are likely to occur over a wide range of cultural conditions.

Conclusion

These results have different implications for grass establishment in the amenity and agricultural sectors. For amenity purposes they indicate that recommended seed rates could be lowered to 8 g m^{-2} (from 25 g m^{-2}) without any increase in weeds. For ryegrass establishment, the converse is true, and a rise in seed rates to between 4 and 8 g m^{-2}, is likely to give improved weed control. Whether such a method of control is cost-effective is an entirely different question, the answer to which depends on many factors, including the economics of weed control in grassland, seed costs and the possible adverse effects of using high plant densities.

Nevertheless, although the limited range of management, weed species and site characteristics encountered in these experiments makes generalisations difficult, the manipulation of grass seed rates does offer some promise as a means of weed control in grasslands and is a subject that deserves further investigation.

References

BEARD, J.B. (1973) *Turfgrass science and culture*. Englewood Cliffs, N.J.: Prentice-Hall Inc.

HAGGAR, R.J. (1979) Competition between *Lolium perenne* and *Poa trivialis* during establishment. *Grass and Forage Science* **34**, 27–36.

HARPER, J.L. (1977) *Populatation biology of plants*. London: Academic Press.

HAWTON, D. (1980) Yield effects of herbicides on competition between crop and weed communities. *Australian Journal of Agricultural Research* **31**, 1075–1981.

LINHART, Y.B.(1976) Density-dependent seed germination strategies in colonizing versus non-colonizing plant species. *Journal of Ecology* **64**, 375–380.

PARR, T.W. (1984) Effects of seed rate on weed populations during grass establishment. *Aspects of Applied Biology* **5**, 117–125.

SNAYDON, R.W. (1982) Weeds and crop yield. *British Crop Protection Conference – Weeds 1982* **1**, 729–739.

WHITE, J. (1980) Demographic factors in populations of plants. In: *Demography and Evolution of Plant Populations*. (Ed O.T. Solbrig) pp.21–48. Oxford: Blackwell Scientific Publications.

ZIMDAHL, R.L. (1980) *Weed-crop competition. A review*. Oregon State University: International Plant Protection Center.

Developments in Selective Weed Control in Newly Sown Leys using Ethofumesate Mixtures

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ABSTRACT

Tank mixtures of ethofumesate with salts of phenoxy acid herbicides antagonise the activity of the former on grass weeds, but mixtures with esters of hydroxybenzonitrile herbicides and benazolin do not show this effect. Ten replicated and seventeen unreplicated 'grower' trials are described which investigated tank mixtures of ethofumesate with a commercially available co-formulation of bromoxynil, ioxynil and benazolin esters, compared with an experimental co-formulation of ethofumesate, bromoxynil ester and ioxynil ester (CR 16804). Commercial recommendations are made for use of the tank mixture, and the co-formulation containing ethofumesate has been launched following the successful outcome of these trials. The significance of broadening the spectrum of ethofumesate to include a wider range of dicotyledonous species is discussed.

Introduction

Preferred pasture grasses (especially ryegrass) show unique tolerance of ethofumesate, but the herbicide is very active against a range of annual weed grasses and *Stellaria media* (Hammond *et al.* 1976). However it has limited activity against other dicotyledons which commonly occur at ley establishment. Control of weeds during the establishment phase is crucial for the achievement of maximum crop quality (Scott & Johnson 1980) and yield (Haggar & Kirkham 1981). It was therefore necessary to find a mixture partner(s) for ethofumesate to broaden the dicotyledon spectrum to include those species frequently found in establishing leys. This paper describes trials with mixtures containing ethofumesate which resulted in the launch in autumn 1984 of a co-formulated mixture (CR16804) containing ethofumesate, ioxynil ester and bromoxynil ester under the trade name of Nortron Leyclene.

Materials and Methods

Two series of trials are reported here. Both series were carried out on new ryegrass leys established and sprayed in autumn 1983.

In the first series ten replicated small plot experiments were established to determine the efficacy and crop safety of a co-formulation containing 200 g/l ethofumesate, 25 g/l ioxynil ester and 50 g/l bromoxynil ester (designated hereafter as CR16804) on new ryegrass leys. Activity of CR16804 was compared with tank mixtures of ethofumesate 20% EC (Nortron) with an emulsifiable concentrate co-formulation containing 125 g/l bromoxynil, 62.5 g/l ioxynil and 50 g/l benazolin, all as esters, with xylene (Asset). CR 16804 was applied at 5 l/ha and commercial products applied at their recommended doses. Treatments were applied with Drake and Fletcher knapsack sprayers fitted with TeeJet 8001 nozzles delivering 200 l/ha at 2.6–3.0 bar. Experiments were conducted on a randomised block layout using 4 replicates with plot size 2 m × 10 m. Double dose treatments were included on one replicate for evaluation of crop safety.

A parallel series of 17 grower trials was laid down with similar objectives and treatments, all of which were sprayed through the farmer's conventional hydraulic sprayer. The trials were unreplicated and plot size was 2 ha/ sprayed treatment. Small areas were left untreated for comparison purposes.

In both series assessments of crop stage and weed species present, and their size were made at spraying. Assessments of crop effects and weed control were made at appropriate intervals thereafter.

None of the trials reported here was harvested. Yield response is the subject of a separate investigation which is in progress.

Results

Table 1: Frequency of occurrence of annual grass weed species (27 trials)

Species	No. of sites	%
Poa annua	22	81
Poa trivialis	4	15
Alopecurus myosuroides	2	7
Avena fatua	5	19
Volunteer barley	9	33
Volunteer wheat	4	15

Table 2: Frequency of occurrence of broad-leaved weed species (41 trials*)

Species	No. of sites	%
Stellaria media	38	93
Matricaria spp.	23	56
Veronica spp.	23	56
Lamium purpureum	17	41
Myosotis arvensis	11	27
Viola arvensis	10	24
Aphanes arvensis	6	15
Capsella bursa-pastoris	6	15
Fumaria officinalis	5	12

*Includes data from a different trials series – not reported here.

Table 3: Antagonistic effects of some mixture partners for ethofumesate

		Volunteer barley control, %	
Treatment	Dose, a.i./ha	161 DAT	194 DAT
Ethofumesate	2 kg	98	93
Ethofumesate + MCPA salt	2 kg + 1.4 kg	76	53
Ethofumesate + dicamba salt	2 kg + 0.1 kg	85	67
Ethofumesate + ioxynil salt	2 kg + 0.2 kg	95	82

Source: Fisons trials 1979/80 (unpublished)

Table 4: Control of broad-leaved weeds, %

Treatment	Dose/ha	*Stellaria media*	*Matricaria* spp.	*Veronica* spp.	*Viola arvensis*	*Lamium purpureum*	*Myosotis arvensis*	Overall b.l.w.
Ethofumesate	1 kg a.i.	95	20	0	0	6	0	–
Ethofumesate + brom/iox/benaz	1 kg a.i. + 2 l product	99	89	99	74	81	100	92
CR 16804	5 l	97	85	99	70	89	80	92
No. of trials		15	8	8	8	5	1	9

Table 5: Control of annual grass weeds, %

Treatment	Dose/ha	*Poa annua*	*Poa trivialis*	*Alopecurus myosuroides*	*Avena fatua*	Vol. barley	Vol. wheet	O/A Ann. grass weeds
Ethofumesate	1 kg a.i.	86	55	93	72	92	78	84
CR 16804	5 l	85	54	92	50	89	76	83
Ethofumesate	2 kg a.i.	87	70	99	92	98	91	92
CR 16804 + etho.	5 l + 1 kg a.i.	84	64	99	94	89	81	91
No. of trials		12	2	2	3	6	4	8

Discussion

The invasion of newly sown leys by weeds commences as soon as the crop is drilled, and progresses to the point where sown species account for 82% of the sward composition at the end of the first year and only 62% by the time the ley is 4 years old (Morrison & Idle 1972). A range of weedy monocotyledons and dicotyledons gradually establishes in the ley, but first to appear, and most abundant, are *Poa annua* and *Stellaria media,* the latter being much more obvious to the casual observer than the former. Volunteer cereals can be a damaging influence at establishment, but do not persist long into the life of the ley. Other annual grass weeds such as *Avena fatua* and *Alopecurus myosuroides* also occur in the establishing ley, but are not so frequent or abundant as *P. annua* (Table 1).

In addition to *S. Media,* other broad-leaved species which occur frequently during the establishment phase are arable weeds like *Matricaria spp.* and *Veronica spp.* (see Table 2), and it is not until considerably later in the life of the sward that typical grassland perennial species like *Ranunculus spp., Bellis perennis, Taraxacum officinale* and *Rumex spp.* appear.

Likewise, as time progresses into the second and third season, the grass weed spectrum often includes *Pos trivialis, Holcus spp.* and *Bromus spp.* As with the dicotyledons, perennial grasses like *Agrostis stolonifera* and *Elymus repens* do not appear until much later.

The damaging effect of weeds which germinate with the crop on the establishment and tillering capacity of the crop grasses is well known (Haggar & Kirkham 1981). The gradual decline of sown species leads to decreased productivity since the weed grasses are generally lower yielding than ryegrass (Haggar 1976). The ability of ethofumesate to control 'weed' grasses and *S. media* in establishing ryegrass has been widely reported (Hammond *et al.* 1976; Griffiths and Hammond, 1978), but suitable mixture partners to give control of *Matricaria spp. Veronica spp.* and *Lamium purpureum* have proved difficult to find. In earlier (unpublished) work, salts of phenoxy acids or dicamba tended to antagonise the activity of ethofumesate against grass weeds while ioxynil salt did not have this effect to such a marked extent (Table 3). However, since optimum effect of ethofumesate treatments accrues from autumn use (Goldsworthy *et al.* 1980) attention was turned to hydroxybenzonitrile (HBN) esters as being more likely to give reliable broad-leaved weed control in the cooler autumn and winter months. Mixtures containing both bromoxynil and ioxynil esters were favoured because of the predominance of *Matricaria spp.* and *Veronica spp.*

A co-formation of bromoxynil, ioxynil, and benazolin esters was used in these trials because of its commercial availability as a 'mixer' product for use on cereals, and an existing recommendation for its tank mixture with ethofumesate on grass. Benazolin was omitted from the co-formulated mixture which included ethofumesate (CR16804) because the principal activity of benazolin lies in the control of *S. media* (adequately covered by the presence of ethofumesate) and *Galium aparine* (not an important weed of establishing grass leys – Table 2).

The very high margin of safety shown by ethofumesate to healthy crops of ryegrass was not impaired in these trials. Some transient scorch occurred when stressed crops were treated or when applications were made in frosty weather. This is normal for HBN herbicides and, in any case, such conditions are not ideal for their activity. Recommendations for use of CR 16804 now exclude treatment of stressed crops in frosty weather.

The addition of the bromoxynil + ioxynil + benzolin product in a tank mix with ethofumesate greatly improved the spectrum of broad-leaved weed control compared with that achieved with ethofumesate alone (Table 4). Good control of the major weeds shown in Table 2 was achieved but performance on *Viola arvensis* and *Aphanes arvensis* was optimised if the weeds were small when sprayed. Best results were obtained from those trials sprayed in moist, warm conditions when weeds were small but growing actively.

Grass weed control from ethofumesate was not antagonised by the presence of broad-leaved weed herbicides in the tank mix or by the co-formulation (Table 5). Whilst ethofumesate requires a dose of 2.0 kg a.i/ha for reliable control of annual grass weeds normally encountered (especially to the standards needed in herbage seed crops), some weeds e.g. *Poa annua* and *S. media* are well controlled by 1 kg a.i./ha and commercial recommendations are now made for use of ethofumesate at this dose to control these weeds. Table 5 shows little improvement in *P. annua* control between 1 kg a.i./ha and 2 kg a.i./ha ethofumesate while for most other grass species and for grass weed control overall 2 kg a.i./ha was needed. In such situations addition of further ethofumesate to CR 16804 by tank mixture is recommended and Table 5 shows that here, too, no antagonism occurred.

CR 16804 thus represents a significant breakthrough in combining the proven activity of ethofumesate against annual grass weeds and *S. media* with the control of a much wider range of broad-leaved species including all those most likely to occur in newly establishing leys (Table 2). The use of HBN esters provides the necessary activity and breadth of spectrum in the cool autumn and winter weather which cannot be supplied by phenoxy herbicides because of the antagonistic effect on the grass weed control by ethofumesate.

The removal of grass weed competition early in the life of the sward has been shown to give significant ryegrass yield response, not only in the year of treatment, but also in the year following treatment (Goldsworthy *et al.* 1980). The simultaneous removal of broad-leaved weeds must assist in the establishment of a vigorous weed/free ley and result in further yield benefit. Work is in progress to measure this.

References

GOLDSWORTHY, J.A.; DUKE, L.G.; WHITEHEAD, R. (1980) Control of weed grasses and *Stellaria media* in grass with ethofumesate. *British Crop Protection Conference – Weeds, 1980* **2**, 483–488.

GRIFFITHS, W.; HAMMOND, C.H. (1978) Establishing weed free swards. In: *Changes in Sward Composition and productivity*. (Eds A.H. Charles and R.J. Haggar). pp.191–197. Occasional Symposium No 10, British Grassland Society, Hurley.

HAGGAR, R.J. (1976). The seasonal productivity, quality and response to nitrogen of four indigenous grasses compared with *Lolium perenne*. *Journal of the British Grassland Society* **31**, 197–207.

HAGGAR, R.J.; KIRKHAM F.W. (1981). Selective herbicides for establishing weed-free grass. I. Evaluation of ethofumesate and methabenzthiazuron. *Weed Research* **21**, 141–151.

HAMMOND, C.H.; GRIFFITHS, W.; VAN HOOGSTRATEN, S.D.; WHITEOAK, R.J. (1976) The use of ethofumesate in grass seed crops. *1976 British Crop Protection Conference – Weeds* **2**, 657–663.

MORRISON, J.; IDLE, A.A. (1972). A pilot survey of grassland in S.E. England. *Grassland Research Institute Technical Report No 10*.

SCOTT, J.L.; JOHNSON, J. (1980). The effect of control of volunteer cereals, grass and broad-leaved weeds on the yield of short term leys. *British Crop Protection Conference – Weeds 1980* **2**, 645–650.

Experiences in Controlling Chickweed with Various Selective Herbicides

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ABSTRACT

Requests for advice on the control of common chickweed Stellaria media *in newly established ryegrass/white clover swards during the late seventies highlighted the fact that there was no label recommendation for the autumn use of the standard clover-safe treatment – benazolin/24DB/MCPA. A trial series was initiated to identify materials which had low temperature activity against common chickweed whilst demonstrating a high degree of clover safety.*

Bentazone/MCPB/MCPA + cyanazine and benazolin/24DB/MCPA achieved a satisfactory level of common chickweed control with moderate clover safeness from the early autumn timings, but the degree of control declined as the weeds achieved size and maturity. Completely clover safe treatments were not identified in this trial series and attention is drawn to a possible interaction between certain herbicides and low temperatures which affects clover survival.

Additionally, the effect of clover sowing date was examined in the absence of a herbicidal treatment. It was concluded that a high proportion of plants from mid/late September germinations were destined not to survive the winter.

Introduction

In recent years there has been a trend toward late summer and early autumn seeding of grass leys. In Scotland, (Richards *et al.* 1984) this has been related to the earlier clearance of land following winter barley. In addition, many farmers are unwilling to direct-seed their grassland in the spring and forego the greater part of the April–July potential dry matter production. Other reasons include death of spring seedings in very hot dry summers, such as those of 1976, 1983 and 1984.

Where white clover (*Trifolium repens*) is included in a seeds mixture and its presence is regarded as 'important', late autumn sowing may pose problems of weed control in the newly establishing ley. Clover is sensitive to many of the commonly used cereal herbicides and this reduces the choice for use in undersown cereals or direct-seeded leys containing clover (Boughton *et al.* 1982).

The situation is further complicated where common chickweed (*Stellaria media*) infests grass/clover mixtures: it is present in nearly two-thirds of autumn sown leys (Anon 1 1984) and can prove extremely damaging to newly sown grasses and clovers.

In the late 1970s colleagues in the MAFF Agricultural Restoration Unit – who are concerned with the restoration of land to agriculture following opencast coal working – posed a weed-control problem which they were finding frequently, i.e. the control of common chickweed in autumn sown leys containing clover. The infestation would manifest itself from September onwards, but the standard clover-safe treatment for chickweed control, benazolin/2 4-DB/MCPA was not recommended for use after the end of August.

With the aim of producing a chickweed control recommendation which colleagues could use on open cast coal sites, a series of trials was initiated by the Northern Region Agronomy Department with the primary objective of identifying herbicides which (a) had low-temperature activity against common chickwed and (b) demonstrated a high degree of clover safety.

Materials and Methods

A trial was laid down in March 1980 on a restored opencast site which had been seeded to perennial ryegrass/white clover the previous autumn.

Herbicides were applied to single unreplicated plots 8 m × 30 m using an MDM Engineering sprayer fitted with Teejet 8002 nozzles. Pressure was 2 bars (CO_2 propellant) and the volume was 200 1/ha.

Table 1: Treatment details

Herbicide	Form	Rate kg a.i./ha	Results Chickweed control	Clover survival
1. Bentazone + MCPB + MCPA	Sol	2.4	*	*****
2. Bentazone + MCPB + MCPA + cyanazine	Sol + Sc	2.4 + 2.5	****	**
3. Bentazone + 2 4-DB	Sol	3.0	***	*
4. 2,3,6,TBA + diacamba + CMPP + MCPA	Sol	1.65	*****	–
5. Benazolin + 2 4DB + MCPA	Sol	1.56	***	**
6. Benazolin + 2 4 DB + MCPA	Sol	3.11	***	*
7. Benazolin + 2 4 DB + MCPA	Sol	4.67	****	*
8. CMPP	Salt	2.85	*****	Tr
9. Ethofumesate	ec	1.0	***	*
10. Bromoxynil + ioxynil	ec	0.8	–	Tr
11. Cyanazine	Sc	1.25	*****	**
12. Linuron	flo	0.25	**	***
13. CMPP + bromoxynil + ioxynil + linuron	ec	1.95	*****	Tr
14. Control untreated			–	*****
15. Control defoliated			***	*****

* – Worst chickweed control or clover survival
***** – Best chickweed control or clover survival

Drainage was unsatisfactory on this site and the residual materials linuron + ethofumesate probably performed badly because of this. The contact activity of the treatments containing cyanazine was adequate to control the chickweed and gave the best balance between weed control and clover survival.

The quickest knock-down effect was noted on treatments 4, 8 and 13, all of which contained growth-regulator type herbicides. This attribute was most important, since the chickweed on these treatments was prevented from seeding whereas, some slow acting herbicides did not prevent seed from being shed before natural senescence occurred.

The more promising treatments were carried forward to a replicated small plot series designed to examine the effect of timing during the winter/early spring period.

Table 2: Effects of various herbicides applied at 3 different timings on clover survival and common chickweed control. (Mean of 2 sites).

Botanical analysis Site (a) 13 May   Site (b) 16 April

Treatment	Rate, l/ha	Clover survival, % 9 Nov	20 Jan	9 Mar	Chickweed control, % 9 Nov	20 Jan	9 Mar
a. Benazolin + 2.4 DB + MCPA (a)	7	74	73	83	54	50	40
b. Benazolin + 2.4 DB + MCPA (a)	14	76	59	62	82	86	69
c. CMPP (60% Salt)	4	6	1	31	98	89	95
d. Cyanazine (50%) (b)	2.5	30	10	21	90	90	81
e. Bentazone + MCPB + MCPA (c)	5	64	59	81	62	32	16
f. Bentazone + MCPB + MCPA + cyanazine	5 + 0.5	62	35	65	85	59	54
g. Linuron (d)	0.83	39	22	52	84	84	68
h. Untreated control	–	100*	100*	100*	–‡	–‡	–‡
MEAN		50	37	56	79	70	60

(a) Product Legumex Extra
(b) Product Fortrol
(c) Product Acumen
(d) Product Rotalin

* Control plot clover plants/m^2 = 22

‡ Chickweed % ground cover on controls = 29.5

Two sites were selected, (a) a restored opencast land at Butterwell, Northumberland; (b) undisturbed land at Blackhall Mill, Northumberland. Weed assessments were made by presence or absence recordings under a grid-type quadrat whilst white clover was assessed by 50 cm square quadrat counts: 20 throws per plot.

Results from these trials were encouraging as, although there was a relatively high level of damage to the clover with all treatments, the degree of weed control was satisfactory from treatments (b) (c) (d) (f) (g) at the November timing.

The January timing coincided with a period of severe weather and produced clover population figures which were depressed in comparison with the earlier and later applications. The effect was noted with each of the herbicides, but the severity of the effect varied. This posed the question, do certain herbicides interact more strongly with low temperatures and thus increase the frequency of clover plant damage or was the variation in effect due partly to chance?

The levels of weed control with all treatments generally decreased with time. This was probably due to the increased weed size or hardiness of the weeds.

The bentazone mixture (e) gave an acceptable level of weed control and this was improved markedly at all timings by the addition of cyanazine (f). Since this combination of two formulated products, together with benazolin + 2.4 DB + MCPA appeared to give the best compromise between common chickweed control and clover safeness, these were included in a national trial series organised by the ADAS Agronomy discipline.

Replicated small plot trials were laid down on perennial ryegrass/white clover swards in the following locations:

1982 Sisters Opencast Coal Site, Widdrington, Northumberland
St Nicholas, Glamorgan
Burnett, Keynsham, Avon
Mortimer, Reading, Berks
1983 East Butsfield, Lanchester, Co Durham
St Brides, Wentloog, Gwent
Wapley, Chipping Sodbury, Avon
Horsham, West Sussex
Mucklestone, Staffs

Treatments were arranged in blocks with randomised sub blocks of early autumn (to 15/11), late autumn (to 31/12), and mid winter timings. Plot size was either 30 m^2 or 40 m^2 and the treatments were applied with a variety of propane-powered small plot sprayers fitted with fan type nozzles.

The use of carbon dioxide as a propellant gas had been found unsatisfactory since a precipitate had been produced in the spray solution of treatments containing bentazone which subsequently clogged the filters.

All treatments were applied in 200–225 1 water/ha at a pressure of 2 bars.

Chickweed control assessments were based on an estimate of percentage ground cover compared with the untreated plots.

White clover was assessed by both area quadrat and point quadrat counts.

Table 3: Impact on sward composition of various herbicides applied during 3 different timing periods 1982/83 and 83/84 (mean of 9 sites)

Treatment Herbicide	a.i., kg/ha	Chickweed control, %			Clover survival, %		
		to 15 Nov	16 Nov– 31 Dec	1 Jan– 31 Mar	to 15 Nov	16 Nov– 31 Dec	1 Jan– 31 Mar
(a) CMPP (salt)	2.4	78	87	68	Tr	3	3
(b) Bentazone + MCPB + MCPA (i)	1.0 + 1.0 + 0.4	64	45	71	40	60	71
(c) Bentazone + MCPB + MCPA + cyanazine	2.4 + 0.15	89	59	83	30	78	62
(d) Bentazone + MCPB + MCPA + cyanazine	2.4 + 0.20	93	61	76	21	67	29
(e) Bentazone + MCPB + MCPA + cyanazine	2.4 + 0.25	95	66	99	18	67	23
(f) Benazolin + 24DB + MCPA (ii)	2.18	93	65	42	41	87	49
(g) Linuron + 24DB + MCPA (iii)	0.98	77	72	–	12	71	–
(h) 24DB + CMPP (iv)	2.1	70	60	–	5	28	–
(i) 24DB + CMPP + cyanazine	2.1 + 0.20	97	68	–	Tr	25	–
(j) Untreated Control	–	Nil	Nil	Nil	100	100	100

(i)Product Acumen
(ii)Product Legumex Extra
(iii)Product Alistell
(iv)Product Nintex

Treatments (g), (h) and (i) were included in 1983/84 only

Cyanazine = product Fortrol

As with the previous trial series, the early autumn herbicide applications tended to give the highest levels of control of chickweed. An exception was the CMPP treatment which gave grossly aberrant results at the Gwent site. Reduced control was noted with the late autumn applied treatments and this could be linked with increasing size and maturity of the weeds. At the Lanchester site however, the vigorous growth of the perennial ryegrass gave a shielding effect toward both weeds and clover and this may have been partly responsible for a reduction in chickweed control from the December herbicide applications.

The most interesting feature was the uniformly poor clover survival data from the early autumn timing. The figures are a mean of 1982/83 – when clover survival was satisfactory – and 1983/84 when it was extremely poor.

An examination of meteorological data for stations nearest to the trial sites revealed that during the last eleven days of October 1983, the grass minimum temperature fell below 0°C on eight or nine occasions, according to site with frosts as severe as −6°C. This period included the first application date at 3 of the sites and immediately preceded it at the remaining 2. In contrast, there were only two occasions during the whole of October 1982 when ground frosts occurred, the lowest recorded temperature being −3.5°C. There is therefore a suspicion that certain herbicidal materials do interact with low temperatures to cause clover plant loss, but without further work in controlled environment conditions with plants of known age or growth stage, it would be difficult to confirm.

In order to quantify the hazards to clover establishment when practising autumn sowing in the absence of herbicides, a replicated small plot trial was laid down at the ADAS Newcastle upon Tyne Sub Centre.

Huia white clover seed was sown without a companion grass at weekly intervals starting on 9 August 1984.

Individual plants were marked and their fate monitored during the winter months. Precautions were taken against slug attack.

Table 4: Effect of date of sowing on % clover plant survival

Date of sowing	% Surviving at 4 February	% Surviving at 12 March
9 August	83	71
16 August	91	66
24 August	80	60
30 August	72	48
6 September	73	58
14 September	79	50
21 September	72	34
1 October	58	8

Discussion

Advisory experience has confirmed that there is a demand within the agricultural industry for herbicides which are capable of removing weeds selectively from autumn sown grass clover swards.

The results of trials carried out during the period 1980–84 have demonstrated that it is possible to remove weeds, particularly chickweed to an acceptable commercial standard, but that on occasions, clover safety falls below the same commercially acceptable standard.

In order to reduce the number of unsatisfactory instances, a farmer must not only be aware of the significance of date of spraying but also the date when the seed germinated. Late germinating seeds being no better than late sown seeds in producing plants which are able to survive the winter, and in providing plants which are at the correct growth stage for treatment by a herbicide. MAFF (1983) confirms that clover does not establish well when sown in late September.

For their part herbicide manufacturers will need to be aware of the proportion of white clover plants which will die, even in the absence of a herbicidal teatment. Otherwise all clover plant losses are likely to be attributed to the effect of herbicide whether or not this is justifiable.

Clearly, a reduction in clover plant stand was caused by all the tretments under investigation. The least damaging were benazolin/24DB/MCPA and bentazone/MCPB/MCPA. The addition of cyanazine to the bentazone/MCPB/MCPA mixture enhanced weed control but there was a dose-related depression in clover survival in most instances.

The linuron/24DB mixture was only tested in the year of high clover seedling loss and therefore its position in the ranking order of clover safety has not been established. The aim of controlling chickweed in autumn sown grass/clover swards whilst experiencing the full range of weather conditions and causing minimal damage to the clover has not been fully achieved. However, improved flexibility of timing and clover safety are possible using bentazone and benazolin (Anon 2 1984). At present neither of these materials has been developed for grassland use as the sole constituent of a herbicide.

Further work is needed to identify the dose rates of these two materials which are required for chickweed control and treatment combinations which will control the full range of autumn germinating weeds without damaging grass or clover.

The trial series is continuing with candidate materials containing bentazone and benazolin together with standards in order to identify improved treatments as they occur.

References

ANON (1) (1984) *AFRC Weed Research Organisation tenth report* 1982–83, p.85.

ANON (2) (1984) *AFRC Weed Research Organisation tenth report* 1982–83, p.85.

BOUGHTON *et al.* (1982) Broad leaved weed control and clover safety of bentazone mixtures used in undersown cereals and direct-sown leys. *British Crop Protection Conference – Weeds* 1982 *1*, 363–367.

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD (1983) Sowing and establishing grassland swards Booklet 2055 6.
RICHARDS *et al.* (1984) *Proceedings Crop Protection in Northern Britain* 1984 333 338.

Discussion on session 1 (R.J. Haggar, session organiser)

Question How much of UK grassland is treated with herbicides?

Haggar According to a 1982 survey by J. Sly, Harpenden Laboratory, about 46% of grassland is sprayed (although this figure might be inflated by spot treatments.
(NB. 999 t a.i. were applied, compared with 16,708 t for cereals – although the latter figure also contains insecticides and fungicides.).

Question What is the best way to sow grass?

Haggar Broadcast, or drill shallowly in two directions, and rib-roll. Use a high seed rate to achieve at least 500 plants/m^2, preferably spaced equidistantly (*i.e.* rectangularity of one).

Question Can chickweed be killed mechanically?

Cooper Yes, by sheep treading, provided the soil type and moisture conditions are suitable.

Question Can TCA be used with ethofumesate to control grass weeds in ryegrass swards?

Whitehead This combination has been used in herbage seed crops (to control volunteer cereals) and in some hay meadows (to control soft brome).

Question Why do clovers die out in the first winter?

Cooper A combination of stress factors, e.g. low temperature, grass shading, weed competition, plus attacks from fungi, slugs etc.

Question Have you looked at longer term changes in sward composition?

Parr Yes, but not in terms of dry matter yields. Weed frequencies in two subsequent years showed a similar exponential decline in relation to increasing seed rate, even though the species changed from being mainly annuals in the established year to mainly perennials later on.

Question How do higher seed rates affect tiller densities?

Parr Tiller numbers per plant decline with increasing seed rate, although plant density increases. Plants are smaller and this may lower resistance to stresses such as trampling and disease.

Question Is the seed rate of 8 g m^{-2} for maximum weed control of general applicability?

Parr Experiments with ryegrass at Monk's Wood have given consistent results. However species with different seed sizes may have different optima. Also other factors such as rate of germination, percentage germination and initial rate of seedling growth will be relevant.

Question With slit seeders, is the spacing between rows important?

Parr A uniform distribution of seed is necessary for increasing seed rate to be effective.

Question Will raising seed rate make it more difficult to establish mixed species?

Parr Where one species is initially more vigorous than another (e.g. ryegrass with clover) then the establishment of the less vigorous species will be inhibited. Where component species have similar seedling vigour, then the differential effect will be slight.

PART 2

PEST AND DISEASE PROBLEMS IN GRASSLAND ESTABLISHMENT

Incidence, Impact and Control of Insect Pests in Newly Sown Grassland in the UK

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ABSTRACT

Work done at a large number of sites in the UK assessing the impact of pests on newly sown grass is summarised. Frit fly larvae (e.g. Oscinella *spp) seemed to be a prevalent pest but various free-living nematodes were also implicated. Damage was worse and occurred more frequently on autumn-sown than on spring-sown grass. The use of minimal cultivation practices exacerbated damage. Italian ryegrass (*Lolium multiflorum*) was more likely to be damaged than perennial ryegrass (*L. perenne*). White clover seedlings were also at risk from pest damage.*

Losses could be minimised by the use of pesticides and various cultural practices. In addition there seems to be some scope for developing resistant grass cultivars and for exploiting the control exerted by naturally occurring parasitoids. Further a new and possibly important development is the use of an endophytic fungus, found to confer resistance to a range of pests on ryegrass plants in New Zealand.

Introduction

During the establishment phase of a crop, little plant material is present and a low number of pest individuals can inflict significant damage. Grass is no exception to this general rule. In the UK the most commonly sown agricultural grasses are perennial (*Lolium perenne*) and Italian ryegrass (*L. multiflorum*) the seedlings of which may be damaged by a number of pests including frit fly (e.g. *Oscinella* spp.), leatherjackets (*Tipula* spp.) and slugs (e.g. *Deroceras*). White clover is sown as a companion species with about 60% of the agricultural grass seeds mixtures used. Seedlings of this important sward component are also susceptible to the depredations of pests including weevils (*Sitona*), slugs and certain namatodes (e.g. *Ditylenchus*).

Damage Assessments

Webley (1958) found that the establishment of a newly sown sward of perennial ryegrass was markedly improved by the application of a pesticide treatment.

During 1977–79 Clements *et al.* (1982) investigated pest damage to 17 spring-sown and 28 autumn-sown swards in England and Wales. Various pesticides were used as experimental tools, applied to small plots on the day of sowing, to suppress pest activity. The effects on tiller density and/or herbage yield were then assessed. There was a response to one or more treatments at most sites, which achieved statistical significance at 20 sites. Most of these were autumn-sowings. Yield was measured at the first cut following sowing for 7 of the autumn-sown swards and was increased on average, by the most effective treatment, by 55% or 0.7 t/ha. Spring sowings seemed less affected.

During 1980–84 similar experiments were done (D.B. Green *et al.* unpublished) at over 30 sites in which the efficacy of a large range of pesticide treatments was assessed, although usually any one treatment was applied only at a small number of sites. There was a trend for most treatments to increase tiller density. Herbage yield was not often measured, but for example at 9 sites in one of the series of experiments where chlorpyrifos was applied (0.72 kg a.i./ha), yields were increased by on average 0.4 t/ha.

Other workers have also evaluated the efficacy of agrochemicals for the control of pests in newly sown grass. For example Lemon & Greig (1982) tested bendiocarb as a seed treatment, a spray and granule formulation. They recorded significant increases in tiller density, some of them very large at nearly all the 11 sites they studied. Mathews & Cottey (1985) assessed the effectiveness of another seed treatment, fonofos, in eight trials during the period 1983–85. Fonofos seed treatment increased numbers of healthy plants and crop vigour. Dry matter yield was also increased at those sites where it was assessed.

The efficacy of low rates of carbosulfan granules was also tested at 16 sites and generally enhanced yield (S.J. Rutherford & S. Higginbotham, unpublished). Paul *et al.* (1985) studied the effects of certain synthetic pyrethroid insecticides on direct-drilled swards and found that they frequently enhanced seedling survival.

Causative Organisms

In much of the above work, for example that by Lemon & Greig (1982), Mathews & Cottey (1985) and Paul *et al.* (1985), most of the damage observed was attributed to frit fly larvae. However in other work it was not always clear which pests were responsible and in some instances (D.B. Green *et al.* unpublished) yield responses occurred in the apparent absence of pests. But comprehensive assessment of all pest species likely to be present is very resource consuming and was often not attempted.

Clements *et al.* (1985) carried out an extensive invertebrate sampling programme in one instance and identified the major causative organism as frit fly with a reasonable degree of certainty. Ellis *et al.* (1984) working in Devon and North Yorkshire and Bentley (1984) working in Berkshire also found that frit fly was the major cause of damage. However, it is likely that in some instances other pests can imperil sward establishment and are also important. For example Spaull *et al.* (1984) found that free-living nematodes can reduce yields of newly sown grass.

Effect of Time of Sowing

A feature of much of the work, is that damage, especially that by frit fly, is worse on autumn-sown grass than on that sown in the spring. This appears to be for two reasons.

Firstly, populations of frit-fly larvae build-up during the growing season and are highest in the autumn (Clements *et al.* 1983). Grass sown in the last week of August seems especially prone to attack, because the emerging seedlings reach their most susceptible stage, *i.e.* 2 leaves (Mowat 1981) when oviposition by frit fly is at its peak.

Secondly, grass seedling growth seems less vigorous and tillering less profuse in autumn-sown swards. Consequently seedlings are less able to grow away from pest attack. Bentley (1984) concluded that the relatively slow growth of grass seedlings in autumn was a more important factor exacerbating damage than the abundance of frit fly. In his work populations of frit fly larvae of 90/m of drill row did relatively little damage to a crop sown in early June, but a lower population decimated a crop sown 3 months later when conditions were less favourable to grass growth.

Direct Drilling versus Conventional Seedbed Preparation

Pest damage can be especially severe when swards are established using minimal cultivation techniques. Ellis *et al.* (1984) compared the effects of ploughing *v.* direct drilling on the invertebrate fauna of grassland. Ploughing, followed by traditional seedbed cultivations greatly reduced the numbers of many species, by exposing them to desiccation, predation by birds and mechanical damage. However, chemical destruction of old pasture by a herbicide preceeding direct drilling did not markedly adversely affect their numbers. Consequently there was a much larger carry-over of invertebrates from the old sward to the newly sown one on direct-drilled areas.

Allen (1981) and Bentley (1984) showed that a large proportion of frit fly larvae are able to migrate from the old to the new sward when direct drilling is practiced and can cause great losses in seedling numbers. However in Bentley's (1984) work losses arising from larvae hatching from eggs laid on the newly emerging seedlings were also an important source of infestation, in addition to those which had migrated. In work at two widely separated sites Ellis *et al.* (1984) also showed that larvae arising from direct oviposition were an important source of infestation.

White Clover

White clover seedlings are also prone to attack by pests. Slot-seeding accentuates the problem. For example Clements & Bentley (1983) found that slot-seeded white clover failed to establish successfully unless protected by a pesticide.

Lewis *et al.* (in press) found spectacular effects on white clover establishment of drilling a pesticide (used as an experimental tool) with the seed on a site infested with stem-nematode (*Ditylenchus*) although Clements & Henderson (1983) had found no significant effects of a pesticide treatment on the establishment of small-lots of white clover.

Control of Pests of Newly Sown Grass

Pesticides

A number of pesticides including chlorpyrifos, cypermethrin and omethoate are approved or recommended for pest control, principally frit fly larvae, during sward establishment. These are effective chemicals but are all spray formulations. This may limit their use to some extent. For example it may be difficult to use spraying equipment on uneven or sloping terrain especially on a crop often grown in small, irregularly shaped fields surrounded by obstructions such as hedges and trees. In recent work the principle of using a range of other pesticides when formulated as seed dressings or as granules for broadcasting or mixing and drilling with seed, has been tested.

The dose-rate of two granular chemicals (phorate and carbofuran) could be greatly reduced if drilled in rows with the seed instead of being broadcast over the entire soil surface (Clements *et al.* 1984). This greatly lessens both the cost and likelihood of damage to the environment.

The granular pesticide carbosulfan, at least under trial conditions, could be mixed with grass seed and sown without modifying the drill (S.J. Rutherford & S. Higginbotham unpublished).

Seed-dressings would be a simple means of using pesticides in this context. Further if an appropriate chemical were used the risk to wildlife and other non-target fauna, e.g. earthworms, would be minimal. Fonofos seed-treatment seems promising, appears to satisfy these criteria (Mathews & Cottey 1985) and would be cheap.

Wherever any pesticide is used, however, care must be taken to ensure there is no unacceptable hazard to wildlife or the environment. Studies are in hand by AGRI on the impact of certain pesticides on the environment when used in grassland.

Resistant Varieties

There are large differences between grass species and cultivars in the extent to which mature plants are infested by frit fly larvae (Clement & Henderson 1977), which may be associated with the distribution of silica bodies in the plant tissue

(Moore 1984). Seedlings may also differ in their resistance to attack (Clements 1979) that it seems feasible that further more resistant cultivars could be bred.

Good Husbandry

Providing conditions conducive to seedling growth is an important factor in minimising damage caused by pests. The use of adequate fertilizer, careful seed-bed preparation and correcting pH where necessary all help seedlings to grow vigorously and be more able to withstand pest attack. There is, for example, some evidence to show that if soil physical conditions are unfavourable for seedling growth, pest attack has a greater effect (Henderson & Clements 1980, Table 1).

Table 1: Effect of insecticide treatment and seedbed tilth on the emergence of Italian ryegrass, 8 weeks after sowing.

	Italian ryegrass seedlings/m^2	
	Untreated	Insecticide treated (10 kg a.i./ha phorate)
Coarse seedbed	113	164*
Fine seedbed	135	164

s.e. diff. (28 d.f.) 16.6

*Significantly different from untreated

Heavy rolling probably helps by closing crevices in which slugs hide and physically restricts movement by other soil pests. However, increasing seed-rate to overcome losses caused by pest attack is not necessarily a wise strategy (Ellis *et al.* 1984; Mowat & Jess 1984). Nor is the use of high levels of N fertilizer which encourages the development and survival of frit fly larvae (Moore 1984).

Parasitoids and other natural enemies

Often 25% and sometimes 70% of frit fly larvae are parasitised by various parasitic wasps, among which *Chasmodon apterus* is common (Moore 1983). Recent work (D. Moore, unpublished) showed that this wasp and others are widespread throughout England and also occur in Wales. Probably they exert a considerable degree of natural regulation over frit fly larval populations. The parasitoid larvae kill their host, but the adult female probes and punctures a number of potential host larvae prior to laying an egg in the larva eventually selected. These puncture wounds probably serve as a place of entry for infection by other organisms (Moore 1983).

Since they are widespread there is some scope for exploiting control exerted by these, and perhaps other, natural enemies. More important however, is the need to ensure that other control methods adopted do not diminish this naturally occurring biological control mechanism. There is perhaps the greatest need to be mindful of this when developing control strategies involving pesticides. However, there are indications, albeit from one trial only, that a range of pesticide treatments had no deleterious effects on the parasitoid population (Table 2).

Table 2: Effect of 11 pesticide treatments on the proportion of frit fly larvae infected by parasitic wasps

Treatment	% frit fly larvae infected with parasitoid
Untreated	35.2
Phorate 1.7 kg a.i./ha	40.0
Phorate 5.0 kg a.i./ha	60.0
Terbufos 1.7 kg a.i./ha	31.3
Terbufos 5.0 kg a.i./ha	27.1
Fonofos 0.72 kg a.i./ha	31.3
Fonofos 1.44 kg a.i./ha	43.8
Carbofuran 5.0 kg a.i./ha	43.9
Chlorpyrifos 0.72 kg a.i./ha	29.7
Chlorpyrifos* 0.72 kg a.i./ha	35.7
Fonofos ST 8 g a.i./kg seed	44.1

*At emergence

This area is receiving further careful attention by the present authors.

Endophyte

An exciting development from work done in New Zealand is the possibility of using an endophytic fungus (*Acremonium loliae*) to control a range of pests in grassland (Barker *et al.* 1984). Recently an endophyte, probably *A. loliae,* has been found in ryegrass plants at five sites in the UK and work is in hand to assess the potential of this fungus for the control of grass pests in the UK (G.C. Lewis, unpublished).

Integrated Control Strategy

There are then several ways in which grass seedling pests can be controlled or at least damage by them minimised. There is now a need to develop a control strategy integrating those elements researched recently and shown to be feasible, cost-effective means of controlling pests in newly sown grass.

Important aspects of this integrated strategy are likely to be simple, cultural methods relating to seedbed preparation and when necessary the use of approved environmentally safe pesticides that do not harm the natural regulation exerted by parasites/predators. Other potentially important methods, e.g. endophytic fungus and perhaps resistant cultivars could be integrated, or may even displace other methods as research progresses.

It seems straightforward to combine control of pests with the control of seedling diseases (Lewis 1985), and may lessen the need for weed control.

Acknowledgement

The Animal and Grassland Research Institute is funded through the Agricultural & Food Research Council and much of the above work was done as part of a Commission for the Ministry of Agriculture, Food and Fisheries.

References

ALLEN, H.P. (1981) *Renewing pastures by direct drilling*. Ipswich: Farming Press.

BENTLEY, B.R. (1984) Stem-boring dipterous larvae as pests of direct drilled grass. *M.Phil Thesis, University of Reading.*

CLEMENTS, R.O. (1979) *Factors affecting the incidence of stem-boring Diptera in agricultural grassland and their effect on yield.* PhD Thesis University of Reading.

CLEMENTS, R.O.; HENDERSON, I.F. (1983) An assessment of insidious pest damage to 26 varieties of seven species of herbage legumes. *Crop Protection* **2**, 491–493.

CLEMENTS, R.O.; HENDERSON, I.F. (1983) Improvement of yield and persistence of Italian ryegrass through pest control. *Proceedings XIV International Grassland Congress, Lexington USA, 1981.*

CLEMENTS, R.O.; CHAPMAN, P.F.; HENDERSON, I.F. (1983) Seasonal distribution of stem-boring larvae including frit fly and pest damage in perennial ryegrass. *Grass & Forage Science* **38**, 283–286.

CLEMENTS, R.O.0 BENTLEY, B.R. (1983) The effect of three pesticide treatments on the establishment of white clover sown with a slot seeder. *Crop Protection* **2**, 375–378.

CLEMENTS, R.O.; JACKSON, C.A.; MOORE, D. (1984) Use of low rates of carbufuran and phorate to enhance Italian ryegrass establishment. *Tests of Agrochemicals & Cultivars 5 (Supplement to Annals of Applied Biology* **104***)* 98–99.

ELLIS, S.A.; BALE, J.S.; ATKINSON, M.; CLEMENTS, R.O. (1984) The influence of permanent pasture rejuvenation technique and pesticide on the incidence of frit fly and yield. *Proceedings Crop Protection in Northern Britain Conference, Dundee 1984*, 299–304.

HENDERSON, I.F.; CLEMENTS, R.O. (1980) The effect of insecticide treatment on the establishment and growth of Italian ryegrass under different sowing conditions. *Grass & Forage Science* **35**, 235–241.

LEMON, R.W.; GREIG, R.J. (1982) The use of bendiocarb in ryegrass establishment. *Pesticide Science* **13**, 523–528.

LEWIS, G.C. (1985) Effect of soil-borne pathogens on ryegrass and white clover seedlings and their control. Proceedings BCPC/BGS Symposium on *Weeds, Pests and Diseases of Grassland and Herbage Legumes*, Nottingham, April 1985, 82–89.

LEWIS, G.C.; CLEMENTS, R.O.; WHITEHEAD, A.G. (in press) Effect on white clover establishment of carbofuran or aldicarb. *Tests of Agochemicals & Cultivars No. 6 (Annals of Applied Biology 105 Supplement)*

MATHEWS, P.R.; COTTEY, A.J. (1985) The effect of fonofos insecticide on the establishment of ryegrass. Proceedings BCPC/BGS Symposium on *Weeds, Pests and Diseases of Grassland and Herbage Legumes*, Nottingham, April 1985, 300.

MOORE, D. (1984) Stem-boring Diptera in perennial ryegrass in relation to fertiliser. I Nitrogen level and form. *Annals of Applied Biology* **105**, 1–6.

MOORE, D. (1983) Hymenopterous parasitoids of stem-boring Diptera in perennial ryegrass in Britain. *Bulletin of Entomological Research* **73**, 601–608.

MOORE, D. (1984) The role of silica in protecting Italian ryegrass from attack by dipterous stem-boring larvae. *Annals of Applied Biology* **104**, 161–166.

MOWAT, D.J.; JESS, S. (1984) The effect of frit-fly on the establishment of autumn-sown ryegrass swards. *Proceedings Crop Protection in Northern Britain Conference, Dundee 1984*.

MOWAT, D.J. (1981) Prediction and prevention of frit fly damage to autumn-sown ryegrass. *Proceedings Crop Protection in Northern Britain Conference, Dundee 1981*.

PAUL, J.A.; WHITAKER, S.F.; HILL, D.M. (1985) Improved grassland establishment by control of Frit Fly with Cypermethrin and Permethrin application. Proceedings BCPC/BGS Symposium on *Weeds, Pests & Diseases in Grassland and Herbage Legumes*, Nottingham, April 1985, 304.

SPAULL, A.M.; CLEMENTS, R.O.; MEWTON, P.G. (1984) The effect of root ectoparasitic nematodes on grass establishment and herbage yield. *Proceedings XIV International Symposium of European Nematologists St. Andrews, Scotland 1982*.

WEBLEY, D.P. (1958) Effect of frit fly on the development of a ley. *Plant Pathology* **7**, 73–74.

Pest and Disease Problems in Newly Sown Grass in The Netherlands

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ABSTRACT

As a result of increasing intensity in the use of grassland, reseeding is a quite common practice. In several cases however the establishment of the new sward is unsatisfactory. Growth retardation especially in the early stage, sometimes leads to complete failure. In established swards damage in the aerial parts of the grass is mainly caused by fungal diseases e.g. crown rust and net blotch. Since control with fungicides is impossible, resistant cultivars are needed. Insects such as leatherjackets and bibionids may incidentally cause damage. Prediction of the damage is difficult by the irregular pattern of occurence. Chemical control in established grass is only permitted against a few insects.

Although viruses in grasses are very common, their role in bringing about crop losses is unknown.

Root attack by nematodes is quite common in grassland. Research proves that in many cases interaction between nematodes and fungi may occur. but nematodes as well as fungi may also cause damage independent from each other.

Introduction

Increased intensity in the use of grassland and an increased use of nitrogen causes a faster ageing of the sward. This results in changes in the botanical composition when less productive grasses and weeds take the place of the more productive ones, reducing the yield drastically. To bring the production to a desirable level, resowing of these pastures in combination with weed control has become a common practice in the last 2 decades (Fig. 1).

The work of Ennik & Baan Hofman (1977) with pesticide treatments in established swards indicated that considerable yield increases could be obtained, showing that pests and diseases do play a role. A wide range of soil borne fungi occur, among which some are known to be noxious to the plants.

Soil fungi are considered a factor that influences the development of the sward, though the use of fungicides proved to be less effective than the use of nematicides.

In the aerial parts of plants fungal diseases are easy to observe, e.g. crown rust, powdery mildew and netblotch may harm the grass plant.

Chemical control with fungicides is not possible and therefore resistant varieties have to be found.

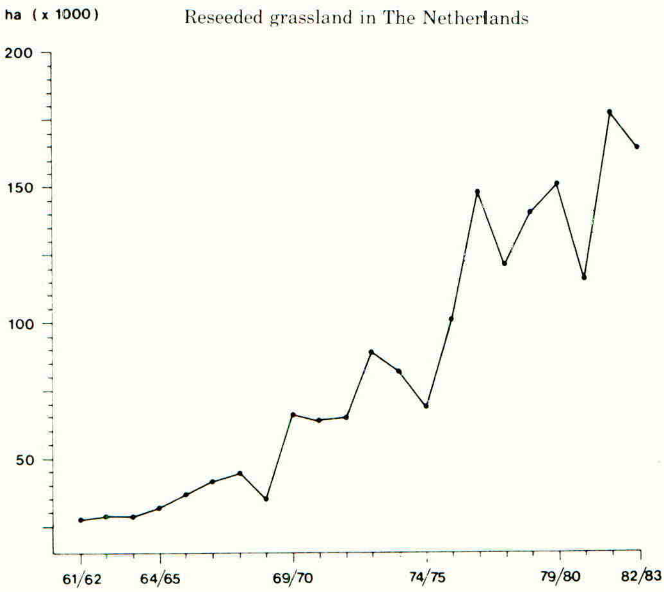

Figure 1: Resown meadows in ha 1962–1983

Although eleven orders of insects occur commonly in established grassland, most of the damage is caused by the representatives of the *Diptera*. Insect damage in grassland is shown by a partly or complete dying of the sward directly after the attack. In most cases this is caused by subterraneously living larvae.

Chemical control of insects is only permitted against a few genera.

Although viruses in grasses are very common, their role in bringing about crop losses is unknown.

Nematodes are always present in grassland and their densities may be high and their damage has been determined in several experiments. Free living nematodes, endoparasitic nematodes, cyst nematodes and root-knot nematodes are all reported as potential enemies of grass plants.

Though research proves that in many cases interactions between nematodes and fungi do exist, nematodes as well as fungi may also cause damage to the crop independent from each other.

Although slugs and moles are very destructive for the sward when they occur, they are not discussed in this paper.

Studies of the different pathogens and their possible interactions with other organisms under field conditions as well as in indoor experiments is part of the work of the Dutch Grassland Working Group. Contacts with Research Institutes in other countries give a wider view to the research approach.

Pests and Diseases

Fungi

Fungi are always found in a wide range of species. Work of Labruyère (1979) mentions 29 species from an experimental field where resowing problems were studied. All species of *Fusarium* together represented 33.5% of all isolates. *Pythium, Phialophora* and *Rhizoctonia* were isolated rarely, although these fungi were often seen as mycelium (*Phialophora, Rhizoctonia*) or as oospores (*Pythium*) on or in the roots. Testing a selection of 22 possible pathogens resulted in the observation that only *Fusarium arthrosporioides* and *F. nivale* were able to kill plants. Most *Fusarium* spp. had only a light or moderate effect on plant growth; all invaded the root cortex as well as the vascular system and were characterized by intercellular growth and formation of cell-wall swellings and lignitubers when mycelium started to grow within cells. Other fungi with a marked influence on the grass plants were *Pythium vanterpoolii,* with an extensive invasion of the root system, especially at low temperature, and *Phialophora radicicola,* also with damage to the root cortex and vascular system.

The appearance of crown roots was delayed in the presence of nematodes and fungal invasion seemed to take advantage from the activity of nematodes in the root. Especially runner hyphae invaded cortial cells at places where nematode damage was evident, but also in places where cells were damaged in other ways.

The presence of the lower fungi e.g. *Lagenocystis radicicola, Olpidium brassicae, Polymyxa graminis, Rhizophydium graminis* and *Sorosphaera radicalis* is quite evident and specially under wet conditions damage to the young root system had been observed.

Fungicide applications did have limited effect on their occurence, it seems that the lower fungi are not affected at all.

Insects

Most of the damage by insects is caused by representatives of the order *Diptera* (Table 1).

Table 1: Composition of the population of insects, spiders and mites. They were collected in one pan trap in 3-years old grassland on clay soil (Nagele, North East Polder), during 18 weeks in the growing season (J. Noorlander, IPO, Wageningen, unpublished data)

Collembola	20.000
Araneidae	5.900
Coleoptera (adults)	3.700
Diptera, Brachycera	1.200
Acarina	1.000
Hymenoptera (parasitica)	1.000
Coleoptera (larvae)	600
Diptera, Nematocera	40
Diptera, (larvae Stratiomyidae)	40
Hymenoptera (Formicidae)	20

Leatherjackets, the larvae of crane flies (*Tipulidae*) cause considerable damage to roots and aerial parts. Though damage is observed in autumn and control measures can be taken, most of the damage is observed in spring when the new development of the sward starts. Sampling and larval counts are carried out and if necessary followed by chemical control, which generally is effective in avoiding damage (Vlug 1985; van de Bund, pers. comm.).

Feverflies, the larvae of *Dilophus febrilis (Bibionidae)* may be very numerous in some years. Unpredictable population changes make damage prediction difficult. Under Dutch conditions the population level seems to become noxious and in lawns and sportfields damage is observed. The larvae cut the tillers just above soil level. Cultural practices may be of influence on the occurence of the larvae of feverflies. It has been observed that after liquid manure (slurry) application damage occurs more frequently. Also poor maintainance of the sward, leaving more dead organic material on the soil is in favour by these insects. Chemical control is permitted (Vlug 1985; van de Bund, pers. comm.).

Frit flies (*Oscinella* spp.) can be an important pest especially for newly sown grasses. Sporadic, but sometimes very serious, damage has been recorded. The role of stemboring larvae in established swards as studied by Clements in the UK (Clements *et al.* 1982) justify a chemical control. The necessity of control is not evident in the Dutch situation, where crop losses are more strongly influenced by other pests which obscure the role of stem-boring larvae in pastures (Vlug 1985; van de Bund, pers. comm.).

Other insects, e.g. gall midges may play an important role in seed crops, but damage in pastures is not recorded. Chafer grubs may incidentally cause damage on established lawns, but never on newly sown grass.

Viruses

From a survey it has become clear that several viruses can be found in grasses. However, as far as known, they play a minor role in causing losses in yields (Beemster 1976).

Ryegrass mosaic virus (RMV) is very common in ryegrasses. Symptoms caused by this virus are rather inconsistent, due to a number of factors such as virus strains, genotype of the host crop and environmental conditions.

Barley yellow dwarf virus (BYDV) can be found in many grass species. Most probably the importance of this virus for grasses is underestimated, but no information about crop losses is available in the Netherlands (Beemster 1977).

Nematodes

Nematodes are always present and may reach very high populations under favourable conditions. Their damage has been determined in several experiments and in observations carried out during the last decades. Studies on the different groups showed that among every group genera can be found which are noxious to grasses. A few examples can be given:

Free Living Nematodes. Studies on *Tylenchorhynchus dubius* (Sharma 1968) indicated the damage of this nematode which is found in many fields in the Netherlands (den Toom & van Bezooijen, Survey, unpublished data) and presently studied for computermodelling.

Root Lesion Nematodes. Oostenbrink (1954) correlated problems in resown meadows with the presence of endoparasitic nematodes belonging to the genus *Pratylenchus*, Thorne (1961) also observed damage by this group of nematodes. Labruyère (1979) reported that fungal invasion seemed to take advantage from the activity of the nematodes in the roots.

Cyst Nematodes. The grass cyst nematode *Punctodera punctata* was recorded in 1950 by Oostenbrink, from Dutch meadows. *Heterodera mani* caused yield losses in experiments carried out by Maas & Brinkman (1977). Field experiments to find resistant or tolerant cultivars were started in 1984.

Root Knot Nematodes. In field experiments for nematode control, *Meloidogyne naasi* caused most of the damage (van Bezooijen 1984). The different life cycles for the different groups and the fact that representatives of the groups are always present in a meadow soil complicates the way of handling the nematode problem. Population fluctuations are well known in nematology and make it difficult to predict nematode damage, especially under conditions where crop rotation is not practiced, as is the case with reseeding.

Although population fluctuations do occur, generally the population develops from low values in spring till a maximum in summer and drops again in autumn (Fig. 2).

Under favourable conditions for grass growth the nematode influence is hardly percepted from the sward development. When stress situations occur however, rather low populations may prove to be noxious, either alone or in combination with other pathogens. Stress situations cannot be predicted, and for agricultural practice we have to overcome the effects on the developing and on the established sward. Reseeding in the Netherlands is mostly carried out in autumn, when according to the graph given in Fig. 2, nematode populations are decreasing. The idea that plant development may suffer less under these conditions is incorrect.

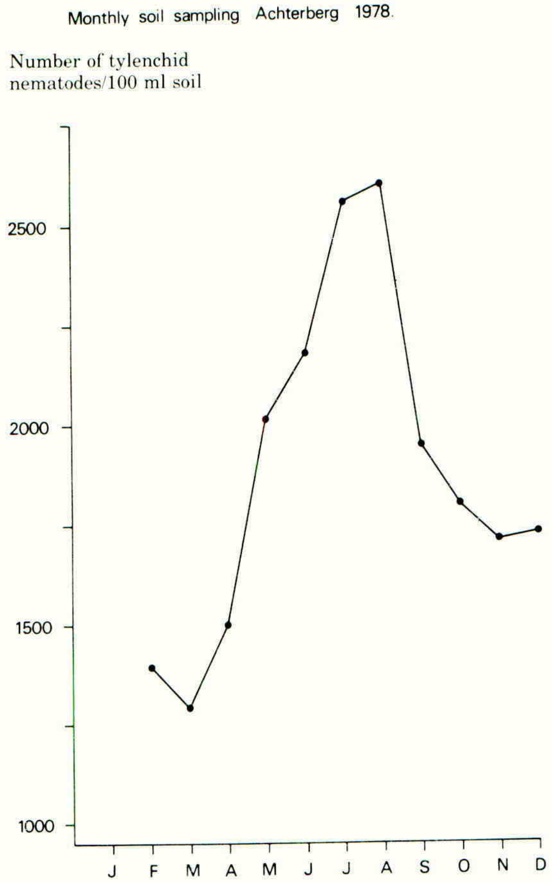

Figure 2: Population fluctuation in 1978

Nematode figures are given in numbers per amount of soil, but due to nematode attraction to the young plant (van Bezooijen 1979), this plant is going to suffer from far more nematodes than are present at the place where the seed is dropped at the time of drilling. Protection of the young seedling therefore is needed.

High amounts of chemicals, however, have to be avoided, since residue tolerances are not developed for grasses. (van Bezooijen 1984). Application of the chemical directly on or with the seed during drilling has been practiced in field experiments and has allowed the use of low dosages.

A specially designed application equipment on the VREDO slotseeder has made it possible to use these low dosages and has proved to establish an even distribution of the chemical in an easily adjustable quantity over the field.

By using low amounts of non phytotoxic nematicides, nematodes are inactivated, thus enabling the young seedling to develop a good root system.

Discussion and Conclusion

Grass is a very important crop in many countries and has long escaped the attention of plant pathologists. Pests and diseases in lawns and golfcourses were the first to draw attention to the grass and due to increased intensity of grassland use, agricultural practice became aware of the existing problems. Chemical control on the aerial parts is often impossible because all the green material is consumed in a short time in large quantities by the animals. Serious insect damage can be controlled by spraying with short duration insecticides which reduce populations and help to overcome the problem.

Looking for resistance or tolerance so far has limited value, though general observations are made for persistance. Mostly physical conditions such as drought and soil type are indicated as the cause of difference in persistance. The impact of pests and diseases has to be taken in account when the results obtained by breeders are evaluated. Testing a range of grass cultivars in field experiments on fields heavily infested with nematodes started in 1984 and will go on. Laboratory tests may prove to be a shorter way to establish persistance among cultivars. Preliminary experiments have already started in our department.

Research to find the indispensable economic threshold levels for each nematode species has started, but more information about interaction among the different nematode species is needed. It is difficult to obtain figures for these threshold levels for the different nematode species because of the occurence of different nematode species in the same field, having different impacts on damage in the grass. Intensive field sampling combined with growth observations will be necessary to obtain more information about the actual damage situation in the field.

Studies on the interaction of nematodes and fungi will continue. Research to avoid the damage of fungal diseases, by limiting the effect of the fungal activity is continuing. Study of the interaction of chemicals and cultural control methods needs attention.

Monitoring frit fly populations including crop loss assessments will go on, but are difficult because of the irregular occurence of the insect. General studies on grassland insects and their impact on the sward will be continued.

The role of fungal pathogens of grassland pest organisms need attention. Stimulation of the naturally existing hyperparasites as done in other parts of agriculture may be of value for grasslands as well.

Experiments on control methods with low dosages of pesticides will go on. Using controlled release formulations, to prolong activity of the chemical on the very low level, is also continued.

The development of dynamic simulation models has been started, but for only a few nematode species. To construct practicable models an enormous amount of work still has to be done.

The promising results of experiments on nematode- and fungal control and the observed influences of cultivars on nematode populations are a sufficiently stimulating factor for the Dutch Grassland Working Group to remain enthusiastic.

Acknowledgements

The author wishes to thank the members of the Grassland Working Group for their enthusiastic help in preparing this paper. The contribution of Dr A.B.R. Beemster on the virus part was very instructive. Dr R.E. Labruyère kindly corrected the text. Mr J. Verhaaf took care of the drawings and Mrs J. Mattaar transferred handwriting to properly typed text.

References

BEEMSTER, A.B.R. (1976). Ryegrass Mosaic Virus in the Netherlands. *Mededelingen Faculteit Landbouwwetenschappen Rijksuniversiteit Gent*, **41/2**, 749–753.

BEEMSTER, A.B.R. (1977). Het gerstevergelingsvirus. *Gewasbescherming* **8(2)**, 55–58.

BEZOOIJEN, J. VAN (1979). Nematodes in grasses. *Medelingen Faculteit Landbouwwetenschappen Rijksuniversiteit Gent*, **44/1**, 339–349

CLEMENTS, R.O., *et al.* (1982). The effect of pesticides on establishment of grass swards in England and Wales. *Annuals of Applied Biology*, **101**, 305–313.

ENNIK, G.C.; T. BAAN HOFMAN (1977). Response of pasture grass to thionazin and other pesticides. *Agricultural Research Reports, Pudoc, Wageningen*, 867, 41 pp.

LABRUYÈRE, R.E. (1979). Resowing problems of old pastures. In: *Soil-borne Plant Pathogens*. (Eds B. Schipper and W. Gams) Chapter 26: 313–326. London, New York, San Fransisco: Acad Press.

MAAS, P.W.TH.; BRINKMAN, H. (1977). Life cycle and pathogenicity of a grass cyst nematode, Heterodera mani, on perennial ryegrass in the Netherlands. *Mededelingen Faculteit Landbouwwetenschappen Rijksuniversiteit Gent*, **42/2**, 1541–1548.

OOSTENBRINK, M. (1950). Het aardappelaaltje (Heterodera rostochiensis Wollenweber), een gevaarlijke parasiet voor de eenzijdige aardappel-cultuur. *Verslagen en Mededelingen Plantenziektenkundige Dienst*, **115**, 230 pp.

OOSTENBRINK, M. (1954). Over de betekenis van vrijlevende wortelaaltjes in Land- en Tuinbouw. *Verslagen en Mededelingen Plantenziektenkundige Dienst*, **124**, 196–233.

SHARMA, R.D. (1968). Host suitability of a number of plants for the nematode Tylenchorhynchus dubius. *Netherlands Journal of Plant Pathology*, **74**, 97–100.

THORNE, G. (1961). *Principles of Nematology*. pp.553. London, New York, Toronto: McGraw Hill Book Company Inc.

VLUG, H. (1985). Some aspects of insect pests in grassland *Mededelingen Faculteit Landbouwwetenschappen Rijksuniversiteit Gent*. (In press).

Effects of Nematodes on Newly-sown Ryegrass

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ABSTRACT

The effects on a spring-sown Italian ryegrass sward of a range of pesticide treatments, irrigation and four fertiliser rates were tested. Nematodes were much fewer where oxamyl had been applied than where it had not; their abundance was not affected by other pesticide treatments. No grassland insect pests or slugs were found.

Yield increases over untreated plots were given early in the establishment year by plots treated with nematicide and later by those treated with insecticide + molluscicide. Response to increasing fertiliser and to irrigation were greater than to pest control.

Nematodes were added to γ-irradiated soil in pots, in numbers equivalent to those in the field trial. Less herbage was harvested when first cut from these pots than from those inoculated with 'nematode-free' soil-washing water or distilled water.

It was concluded that root-ectoparasitic nematode populations can damage establishing ryegrass and can be more serious pests to a spring-sown sward than insects.

Introduction

Plant parasitic nematodes have been implicated in poor establishment of ryegrasses, both in Holland (Bezooijen 1979) and in the UK (Spaull & Mewton 1984; Spaull *et al.* 1985). However, the chemicals used to give nematode control in the field are also effective insecticides and the effect upon grass establishment of nematode attack alone has not been demonstrated clearly.

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Sward management, e.g. fertiliser rates and irrigation, can affect establishment and subsequent herbage yields directly but may also influence the expression of pest damage. This was investigated in the field.

The effects of nematodes on ryegrass establishment was also measured in pots.

Materials and Methods

Field Trial

A seedbed was prepared on a sandy loam soil at Hurley, Berkshire. Italian ryegrass cv. RvP was sown on plots 1.5 m × 6 m long at a rate of 1,200 viable seed m^{-2}, using an Øyjord drill. A basal application of 20:10:10 ($N:P_2O_5:K_2O$) fertiliser was given to all plots to supply 50 kg N ha^{-1}; additional fertiliser was also applied as 20:10:10 in three equal top dressings, to appropriate plots, to give annual totals of 50, 200, 400 and 900 kg N ha^{-1}. Pesticide treatments are listed in Table 1 and were applied first within 5 d of sowing. Irrigation was given to return plots to field capacity at the beginning of each week when a 2.5 cm potential soil moisture deficit existed.

Table 1: Pesticide treatments

Treatment	Material	Rate	Timing
Nematicide	Oxamyl	5.0 kg a.i./ha	in seedbed and after each cut
Insecticide	γ–HCH	3.3 kg a.i./ha	to seedbed
	Chlorpyrifos	1.5 kg a.i./ha	to seedbed and after each cut
+			
Molluscicide	Methiocarb	0.7 kg a.i./ha	to seedbed and after each cut
Fungicide	Propiconazole	0.13 kg a.i./ha	to seedbed and after each cut
	Aluminium tris ethyl phosphonate	3.0 kg a.i./ha	

Soil was sampled for nematodes to a depth of 15 cm with a 4 cm diameter auger and nematodes were extracted passively from 200 ml (volume displaced in water) subsamples by a method simplified from Seinhorst (1955). The extract was cleaned by centrifugation in sucrose solution (Coolen & d'Herde 1977). Cyst nematodes were assessed by extraction from a further 100 g of soil (Trudgill *et al.* 1972). Other macro-invertebrates were extracted from cores 10 cm diameter and

15 cm deep by a wet-sieving method (Salt &Hollick 1944). Soil was sampled before the trial and at the end of the year. Additional samples were taken 12 days after sowing and nematodes were extracted from 100 g subsamples by a method where efficiency is determined by nematode activity (Whitehead & Hemming 1965). Tiller infestation by stem-boring Diptera was assessed by examining c.100 tillers/plot, collected in January of the following year.

Plots were harvested and weighed using a Haldrup harvesting machine on July 14, August 26, October 19, and November 14, 1983.

Pot Test

Soil from the trial field (above) was screened through a 1 cm mesh sieve. Some of the soil was sealed into polythene bags (c.3 l/bag) and received 2.5 Mrads γ-radiation. Bags were kept for 13 d at 4–7 C before opening, for convenience. Soil was mixed 24 h before use and nematodes were extracted passively from six, 50 ml subsamples (volume displaced in water), as above; to check the efficacy of irradiation. Remaining treated soil was used in 3 l portions to fill 18 cm (diam.) pots.

Nematodes for inoculation were extracted from 1 l portions (approx.) of the untreated soil, by elutriation (Oostenbrink 1960). Extracts were bulked then cleaned and concentrated by sucrose centrifugation (as above). The aqueous supernatant from the first centrifugation (usually discarded) was kept for control inocula and 6 subsamples were examined for contaminating nematodes. Nematodes collected from the second centrifugation were bulked and nematode inocula prepared to give numbers similar to the original field population. Further control pots were inoculated with distilled water.

All pots were given 40 ml of the appropriate inoculum, poured into a shallow depression in the central 12 cm of soil. The surface was re-levelled and 14, 5-d-old seedlings of *Lolium multiflorum* cv. RvP were planted in the inoculated area. Seven days later each pot received the equivalent of 100:50:50 kg ha^{-1} of $N:P_2 0_5:K_2 0$ fertiliser. Pots were kept in a glasshouse at 7–17°C with 16 h lighting daily.

Grass was clipped to 5 cm, 68 days after planting and the herbage dry matter weighed after 24 h at 80°C.

Results

Field Trial

Yields at the last cut were small (mean = 0.24 t/ha) and the results from this harvest are not presented individually but were included in the annual total.

Yields on plots treated with pesticides were greater than from untreated areas; the fungicide had no measurable effect on yield. Yields from plots treated with nematicide were greater than those from comparable untreated plots at the three main harvests but the increases were greater at the first and second cuts than at the third (Table 2).

Table 2: Yields d.m. in relation to pesticide application, t ha^{-1}

	Nematicide			Insecticide + molluscicide	
	–	+	s.e.d.	–	+
Cut 1	2.90	3.17	0.045	3.01	3.06
Cut 2	2.76	2.96	0.068	2.78	2.95
Cut 3	2.27	2.37	0.032	2.22	2.42
TOTAL	8.17	8.75	0.107	8.21	8.69

(means of 64 replicates)

Yields from plots treated with the insecticide + molluscicide did not differ appreciably from comparable untreated plots at the first cut but at the second and third cuts treated plots yielded more than those untreated (Table 2).

Yields were increased compared with untreated areas where fertiliser and/or irrigation had been applied, as might be predicted (Table 3). Increases following irrigation were sometimes large, especially mid-season (e.g.: 1.39 t/ha unirrigated; 4.34 t/ha irrigated; $P<0.001$). Detailed results are not published here for brevity.

Table 3: Yields d.m. from irrigation and for fertiliser rates, t ha^{-1}

Fertiliser N kg ha^{-1}	50	200	400	900
	6.88	8.42	9.11	9.42
Irrigation	–	+		
	5.96	10.96		

(Fertiliser means of 32 replicates; irrigation means of 64 replicates)

No insects pests of grassland or slugs were found at the start of the trial but an estimated 17,300 plant-parasitic nematodes/litre soil were present. Three species were abundant: *Tylenchorhynchus* (mostly *T. dubius*) 5,900/l; *Helicotylenchus varicaudatus* 5,400/l and 4,000 *Paratylenchus microdorus/l*. The cyst nematode *Heterodera avenae* was also present at 1.4 eggs/g moist soil.

Table 4: Number of plant parasitic nematodes extracted from soil 12 days after sowing

Treatment	Nematode nos/50 g soil	
	Untreated	Treated
Fungicide	206	190
Insecticide/molluscicide	200	193
Nematicide	259	142***

(Means of 64 replicates; analysed after log $_{(N + 0.5)}$ transformation)
*** P<001

Active plant parasitic nematodes were more numerous from untreated than nematicide-treated soil (Table 4); no other treatments had a significant effect. Nematodes were least abundant at the end of the year where nematicide had been applied and abundance seemed unaffected by other pesticide treatments (Table 5). The cyst nematode count at the end of the year from untreated plots had not altered from the initial numbers and treated plots were therefore not sampled. No soil-inhabiting grassland insect pests or slugs were found and tiller infestation by stem-boring Diptera was not detected.

Table 5: Nematode nos/l soil at the end of the year

Treatment	Untreated	Treated
Fungicide	10,780	12,170
Insecticide/molluscicide	12,080	10,870
Nematicide	16,780	6,170***

(Means of 64 replicates; analysed after log $_{(N + 0.5)}$ transformation)
*** P<0.001

Pot Test

An estimated 5,300 plant parasitic nematodes/l soil survived irradiation; this included 2,000 *Tylenchorhynchus*/l, 2,100 *Helicotylenchus*/l and 1,000 *Paratylenchus*/l but was significantly fewer ($P<0.001$) than numbers inoculated to each litre of soil (Table 6). The soil-washing water from the first centrifugation only contained a very small number of nematodes (Table 6) and the distilled water was nematode-free. Significantly less grass was cut from nematode-inoculated pots than from other treatments.

Table 6: Nematode inocula (nos/l soil) and grass clipping weights (d.m. g/pot)

Inoculum	Distilled water	Extraction water	Nematodes
Tylenchorhynchus	0	16	12,450
Helicotylenchus	0	0	3,330
Paratylenchus	0	3	3,550
Total plant-parasitic nematodes	0	21	20,770
Clipping wt. (s.e.d. = 0.324)	3.83	4.32	2.38***

(means of 8 replicates)
*** $P<0.001$

Discussion

The nematicide oxamyl is also an effective insecticide but the insecticide + molluscicide treatment used products not considered to affect nematodes (Spaull & Mewton 1982; Bromilow pers. comm.). The results supported the expected selectivity, as neither nematode activity nor end-of-season numbers were altered by any treatment other than the designated 'nematicide'.

The first harvest showed no response to the insecticide + molluscicide treatment but yield was increased following oxamyl use, indicating that the lost yield on untreated plots resulted from nematode attack. Ectoparasitic nematodes were probably responsible as so few cyst nematodes were present and did not increase. Later yield increases were probably due largely to insect control as yield gains following nematicide use were similar to those following treatment with insecticide + molluscicide.

No soil-inhabiting insect pests were found, nor were tillers infested with stem-boring Diptera when sampled the following January. The larval population has been considered to be fairly stable from autumn until January (Clements *et* *al.* 1983) but more recent work has suggested that infestations may start to decline earlier than this (Clements pers. comm.), which seems to have occurred in this trial. However frit fly are most numerous during July and August and larvae are active within swards in the succeeding months. Frit fly were the most likely cause of yield loss at the second or third harvests.

There were no interactions between pesticide treatments and either fertiliser rates or irrigation; *i.e.* pest-related yield loss was independent of these factors. However, the mean annual yield achieved by pest control was only exceeded by plots receiving 400 kg N ha^{-1} or more fertiliser annually.

Responses to fertiliser and irrigation are not central to the main theme of this paper but were noted usually to be much greater than to pesticides. These findings will be fully presented elsewhere.

Results from the pot test confirmed those from the field. Despite a residual nematode population in the irradiated soil, pots inoculated with further nematodes had significantly larger numbers. These pots yielded appreciably less than other treatments. It is concluded therefore that root-ectoparasitic nematodes can be damaging to ryegrass at establishment and that they can be more harmful to a spring-sown sward than insect pests or disease.

Acknowledgements

The trial was conducted at the Grassland Research Institute, with much assistance from Dr R.O. Clements and other staff. The Grassland Research Institute and Rothamsted Experimental Station are both funded by the Agricultural and Food Research Council.

References

BEZOOIJEN, J. VAN. (1979) Nematodes in grasses. *Mededelingen Faculteit Landbouwwetenschappen Rijksuniversiteit Gent* **44**, 339–349.

CLEMENTS, R.O.; CHAPMAN, P.F.; HENDERSON, I.F. (1983) Seasonal distribution of stem-boring larvae including frit fly (Diptera: *Oscinella frit* L and pest damage in perennial ryegrass. *Grass and Forage Science* **38**, 283–286.

COOLEN, W.A.; D'HERDE, C.J. (1977) Extraction de *Longidorus* et *Xiphinema* spp. du sol par centrifugation en utilisant du silice colloidal. *Nematologia Mediterranea* **5**, 195–206.

OOSTERBRINK, M. (1960) Estimating nematode populations by some selected methods. In: 55Nematology. (Eds J.N. Sasser and W.R. Jenkins) pp. 85–102. Chapel Hill: University of North Carolina Press.

SALT, G.; HOLLICK, F.S.J. (1944) Studies of wireworm populations. 1. A census of wireworms in pasture. *Annals of Applied Biology* **31**, 53–64.

SEINHORST, J.W. (1955) Een eenvoudige methode voor het afscheiden van aaltjes uit grond. *Tijdschrift over Plantenziekten* **61**, 188–190.

SPAULL, A.M.; MEWTON, P.G. (1982) Effect of four insecticides upon soil-inhabiting nematodes. *Tests of Agrochemicals and Cultivars (Annals of Applied Biology 110, Supplement)*, No. 3, pp. 34–34.

SPAULL, A.M.; MEWTON, P.G. (1984) Poor establishment and yield losses of cereals and grasses caused by trichodorid nematodes. *Proceedings Crop Protection in Northern Britain*, 1984. pp. 49–54.

SPAULL, A.M.; MEWTON, P.G.; CLEMENTS, R.O. (1985) Establishment and yield of three ryegrasses following aldicarb use, and changes in abundance of plant parasitic nematodes. *Annals of applied Biology*, **106.**

TRUDGILL, D.L.; EVANS, K.; FAULKNER, G. (1972) A fluidising column for extracting nematodes from soil. *Nematologica* **18**, 469–475.

WHITEHEAD, A.G.; HEMMING, J.R. (1965) A comparison of some quantitative methods of extracting small vermiform nematodes from soil. *Annals of Applied Biology* **55**, 25–38.

Permanent Pasture Rejuvenation and the Invertebrate Population

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ABSTRACT

Collembola, mite and earthworm populations and herbage dry matter yield were assessed under three permanent pasture rejuvenation techniques: (1) Plough and reseed, (2) direct drilled reseed and (3) fertiliser application to the existing sward, treated and untreated with aldicarb. Invertebrate populations were assessed on four occasions over a 9 month period and herbage yield at four harvests over 1 year. Cultivation reduced the numbers of mites, collembola and earthworms. These effects were short lived although different earthworm species showed different rates of recovery from this treatment. Aldicarb treatment initially decreased populations of microarthropods and some earthworm species. Yields of herbage dry matter were much greater in pesticide treated plots of the reseeds, probably due to the control of frit fly larvae.

Introduction

The aim of permanent pasture rejuvenation is to stem and reverse deterioration of an established grass sward and increase output. There are a number of methods available to achieve this improvement which differ in their degree of soil disturbance. These include, ploughing the old sward and reseeding, chemical desiccation of the old sward and direct drilling and application of fertiliser to the old sward plus intensifying management.

Clearly such cultural practices may have considerable effects on the resident grassland invertebrate populations, which can be very large. Further, the perennial nature of permanent grassland allows established predator/prey, host/parasite relationships to develop which may become imbalanced by the adoption of pasture improvement techniques. It was the aim of this research to study how grassland invertebrates were affected by pasture rejuvenation.

Materials and Methods

A field experiment was done at the University of Leeds Field Station near Tadcaster, Yorkshire. The trial site was established in August 1982, with a restricted randomised block design consisting of four treatments; (1) conventional cultivation and reseeding, (2) direct drilling, (3) fertiliser application to the existing sward, and (4) untreated control. There were 5 replicates of each treatment in plots of size 12 × 5 m with aldicarb applied on a split plot basis at 5 kg a.i./ha. Both the conventional reseeding and the direct-drilled plots were sown with a Moore Unidrill on 12 August. Fertiliser was applied at drilling to all plots except the control at a rate of 80, 40 and 40 kg ha^{-1} N, P_20_5 and K_20 respectively.

Microfauna populations were assessed on the day of sowing by taking four 5 cm diam., 15 cm deep soil cores per split plot. Samples were taken again in September and October 1982 and May 1983. The microfauna were extracted using a modified Tullgren, high gradient extraction apparatus except in August 1982, when flotation in saturated magnesium sulphate was used.

Earthworm populations were assessed on the same dates using a formalin drench (0.66% solution) technique (Raw 1952) on two 60 × 60 cm quadrats/split plot. Earthworms brought to the surface were collected, counted and identified.

Herbage yield was assessed in October 1982 and May, June and August 1983 using a Haldrup plot harvester. Sub samples (c. 500 g) of the fresh herbage were dried to determine the dry matter content.

Results

i) Collembola and Mites

Analyses of variance were performed on the total numbers of collembola and mites recovered from plots under different methods of pasture improvement with and without aldicarb, on all sampling occasions. These have been summarised graphically in Figs 1–4. There is evidence of seasonal changes in microfuana populations. However, these are of little relevance in the present study and more attention will be paid to the effect on the microfuna of the treatments applied.

Figs 1 and 3 provide a summary of the mean numbers of collembola and mites recovered from plots under different pasture improvement methods (means of insecticide treated and untreated). Significantly fewer collembola were found in ploughed plots than in all other treatments on the first two sampling occasions (August 1982, $P<0.05$; September 1982, $P<0.05$). However, on the final sampling occasion in May 1983 there was little difference between all four treatments.

Aldicarb significantly reduced collembola numbers in the direct drilled reseed 4 weeks after its application ($P<0.05$, Fig. 2). Populations in the ploughed treatment were also depleted by aldicarb but not significantly. Subsequently, differences between split plots with and without aldicarb decreased and in the May assessment numbers in treated split plots exceeded those in their untreated counterparts.

Numbers of mites were generally lowest in the ploughed and greatest in direct drilled plots (Fig. 3).

Mite populations were significantly reduced in direct drilled plots 4 weeks after pesticide had been applied ($P<0.05$) and this difference was maintained until the second sampling (Fig. 4). Numbers of mites in the ploughed reseed were greater in untreated split plots than in their treated counterparts but this difference was not significant. At the May sampling there was little difference between areas with and without aldicarb in either ploughed or direct drilled plots. Trends in the control and fertiliser only plots were similar.

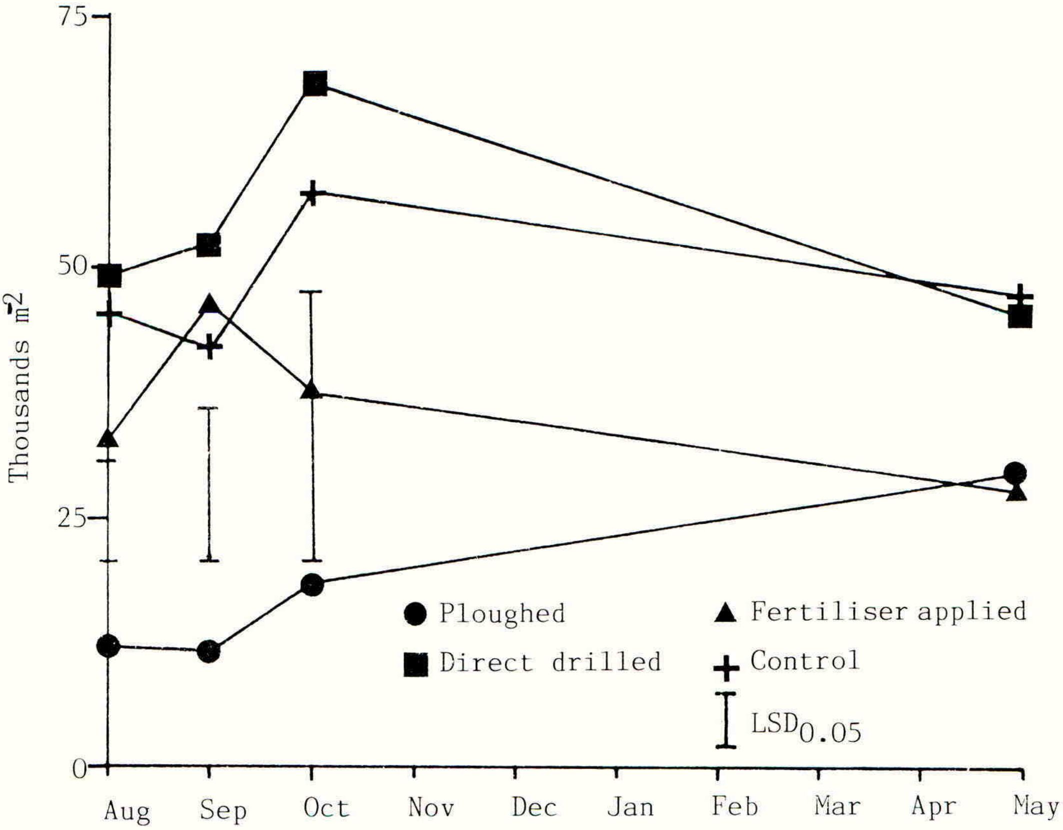

Figure 1: Mean numbers of collembola m^{-2} from plots under different methods of pasture rejuvenation

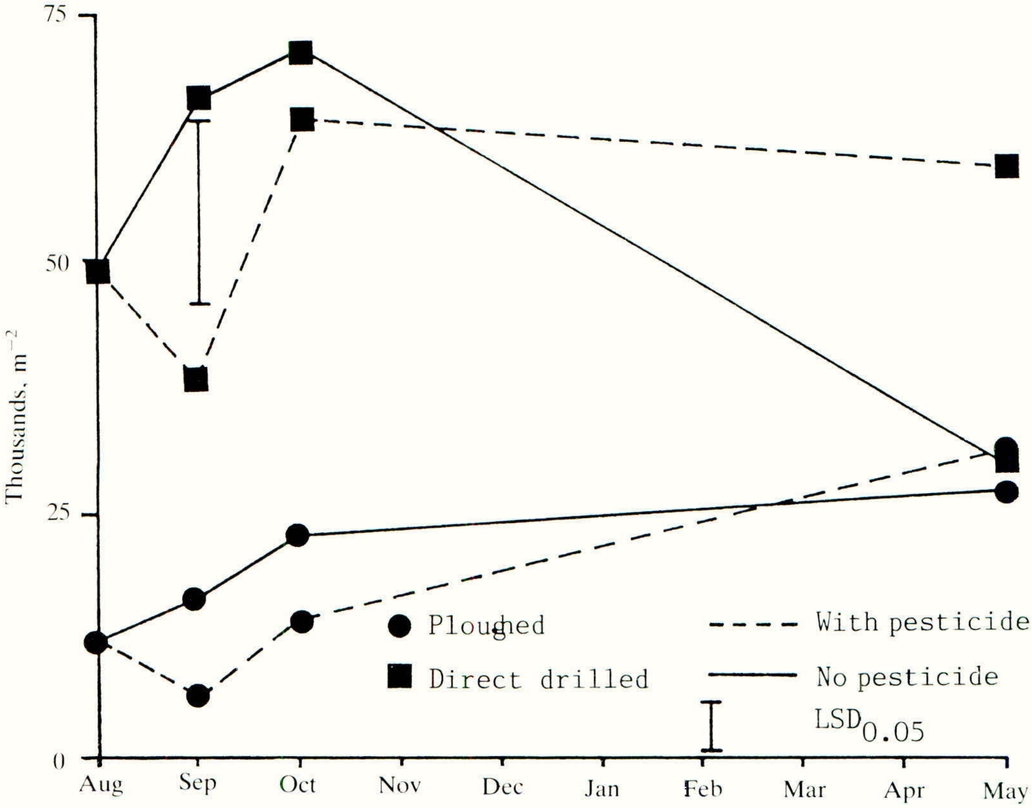

Figure 2: Mean numbers of collembola m^{-2} from plots under different methods of pasture rejuvenation with and without aldicarb

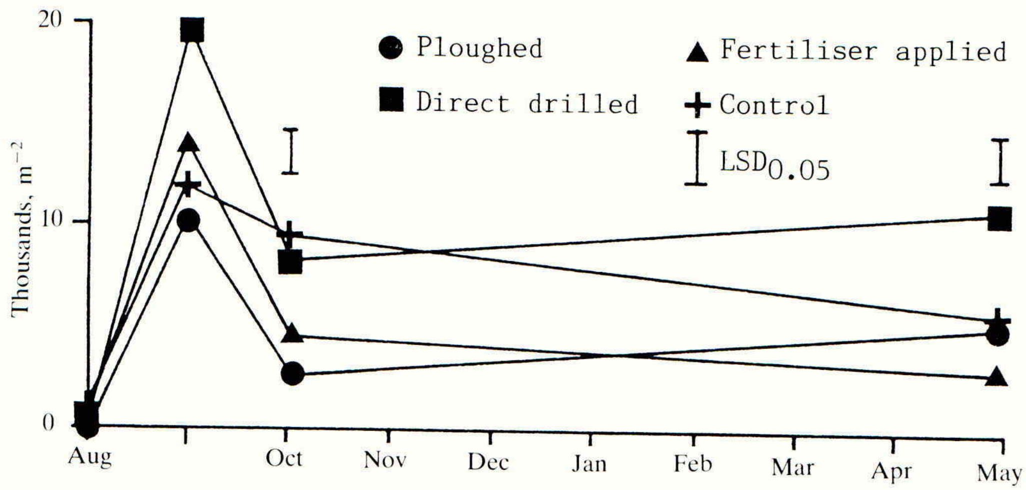

Figure 3: Mean numbers of mites m^{-2} from plots under different methods of pasture rejuvenation

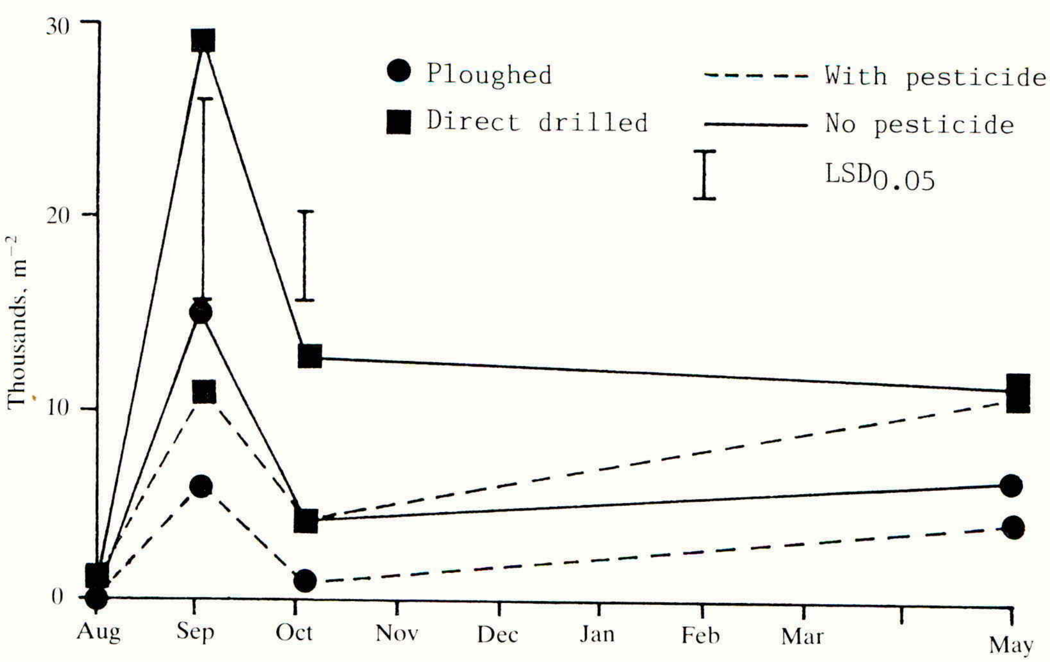

Figure 4: Mean numbers of mites m^{-2} from plots under different methods of pasture rejuvenation with and without aldicarb

ii) Earthworms

Analyses of variance were performed on the most abundant species recovered from all treatments on all sampling occasions. Total numbers of earthworms recorded on the day treatments were made and on the second sampling occasion 4 weeks later were low and as a result numbers of individual species were not analysed. Table 1 gives a summary of the total earthworm analyses carried out on these dates. On both sampling occasions the numbers of earthworms recovered from the direct drilled reseed were significantly greater than in all other treatments ($P<0.05$) whether treated with aldicarb or not.

Table 1: Mean numbers of earthworms recovered from plots under different methods of pasture improvement in August and September 1982. (earthworms m^{-2})

(a) *August 1982*	Ploughed	Direct drilled	Fertilisr applied	Control	Mean
		14.6	2.8	3.9	

a = 5.77

Rejuvenation techniques significantly different $P<0.001$

(b) *September 1982*	Ploughed	Direct drilled	Fertilisr applied	Control	Mean
With aldicarb	2.0	7.6	1.4	1.1	3.1
Without aldicarb	3.1	12.0	0.6	2.5	4.6
Mean	2.5	9.8	1.0	1.8	

a = 3.72

Rejuvenation techniques significantly different $P<0.001$

The results of analyses performed on the 3rd sampling occasion in October 1982 are summarised in Table 2.

There were marked differences in the numbers of individual species in split plots with and without aldicarb treatment. Pesticide reduced populations of *Allolobophora longa* and *Allolobophora chlorotica* ($P<0.001$ and $P<0.05$ respectively) whereas, higher numbers of *Lumbricus terrestris* were recorded in split plots with aldicarb application ($P<0.001$). Only numbers of *A. longa* differed significantly between treatments in a final earthworm assessment in May 1983. Populations of this species were greatest in insecticide treated split plots ($P<0.05$).

Table 2: Mean numbers of earthworms recovered from plots under different methods of pasture improvement in October 1982 (earthworms m^{-2})

(a) *Lumbricus terrestris*	Ploughed	Direct drilled	Fertiliser applied	Control	Mean	
With aldicarb	3.6	4.2	2.8	1.7	3.1	b=1.32
Without aldicarb	1.7	0.6	1.4	1.4	1.3	
	c=2.63		d=2.72			
Mean	2.7	2.4	2.1	1.5		

Pesticide treatments significantly different $P<0.001$

(b) *Allolobophora longa*	Ploughed	Direct drilled	Fertiliser applied	Control	Mean	
With aldicarb	2.2	1.4	2.0	3.6	2.4	b=2.18
Without aldicarb	5.0	8.4	6.7	6.7	6.7	
	c=4.37		d=4.14			
Mean	3.6	4.9	4.3	5.2		

Pesticide treatments significantly different $P<0.001$

(c) *Allolobophora chlorotica*	Ploughed	Direct drilled	Fertiliser applied	Control	Mean	
With aldicarb	1.1	0.8	0.6	0.6	0.8	b=1.78
Without aldicarb	0.6	5.9	2.5	2.2	2.8	
	c=3.54		d=3.11			
Mean	0.8	3.4	1.5	1.4		

Pesticide treatments significantly different $P<0.05$

iii) Herbage Yield

Table 3: Mean yield of herbage dry matter from plots under different methods of pasture rejuvenation over 4 harvests (t ha^{-1})

	Ploughed	Direct drilled	Fertiliser only	Control	Mean	
With aldicarb	13.55	13.26	13.04	7.67	11.88	b=0.66
Without aldicarb	9.48	10.74	12.53	7.58	10.08	
	c=1.21		d=1.09			
Mean	11.52	12.00	12.79	7.63		
		a=0.68				

Significance of main effects: Rejuvenation technique $P<0.001$;
pesticide $P<0.001$;
interaction $P<0.001$.

a = $LSD_{0.05}$ for rejuvenation technique

b = $LSD_{0.05}$ for pesticide means

c = $LSD_{0.05}$ for vertical comparison in table

d = $LSD_{0.05}$ for horizontal and diagonal comparisons in Table.

Discussion

Both pesticide application and cultivations reduced numbers of mites and collembola but the effects were transient.

When a soil is left undisturbed, as in old pasture, a mat of decaying or partly decayed organic matter develops in which large numbers of invertebrates are concentrated. When this is ploughed the invertebrate population is dispersed in the top 15 cm and is depleted through mechanical damage, desiccation at the soil surface and predation by birds (Edwards 1977). Edwards & Lofty (1975) suggested that once cultivation had ceased populations of arthropods soon return to their previous levels. In this experiment collembola and mites began to recolonise ploughed plots from 10 weeks after treatment. There was little difference in collembola numbers between different improvement methods and the control 9 months after treatment. Recolonisation of cultivated land is likely to be partly aerial and partly through microarthropods simply walking in (Bauhin & Edwards 1964), thus unless very large areas are planted with arable crops over very long periods, it is unlikely that the soil microarthropod population would be seriously depleted or affected by cultivations (Edwards & Lofty 1975).

Aldicarb reduced both mite and collembola populations, but only initially. Mites appeared to be more sensitive to aldicarb application than the collembola. This may be due to the Mesostigmata being the most numerous mite group recovered. They are primarily a predatory group and as a result very active, thus increasing their chance of contacting the pesticide (Edwards 1977). Also, pesticide treatment would tend to reduce the numbers of prey species available for these mites and thus the populations may be adversely affected in this way.

The collembola appeared to recover quickly from aldicarb treatment and significant differences between split plots with and without pesticide were only found up to 4 weeks after application.

Total earthworm numbers were reduced in ploughed plots on the day of treatment and 4 weeks subsequently. Ploughed plots were harrowed and rolled twice prior to drilling and there is evidence that earthworms were adversely affected by these management practices.

Different earthworm species showed different rates of recolonisation of ploughed plots. There was little difference in numbers of *L. terrestris* and *A. longa* between ploughed and direct drilled reseeds 10 weeks after establishment, whereas numbers of *A. chlorotica* remained low in the ploughed reseed 9 months later. *A. longa* and *L. terrestris* are deep burrowing species (Edwards & Lofy 1977) and some individuals may have avoided damage from cultivation by withdrawing into their burrows.

The response of earthworms to pesticide treatment varied between species. Numbers of *L. terrestris* were greater in aldicarb treated split plots 10 weeks after drilling whereas *A. longa* and *A. chlorotica* were more numerous in untreated areas. As *A. chlorotica* is usually found close to the soil surface it is more likely to contact the pesticide. Consequently reductions in numbers of this species following application are not surprising.

There was no evidence of a detrimental effect of pesticide 9 months after application and numbers of *A. longa* were greatest in areas to which it had been applied.

Conclusion

Cultivation reduced the numbers of mites, collembola and earthworms. These effects were short lived although different earthworm species showed different rates of recovery from this treatment. Aldicarb treatment greatly decreased microarthropod and some earthworm species populations initially, but there was no obvious deliterious influence on soil structure or organic matter turn over. Yields of herbage dry matter were much greater in pesticide treated split plots of the reseed treatments probably due to the control of frit fly larvae (Ellis *et al.* 1984).

Acknowledgements

I would like to thank the University of Leeds Field Station for the provision of the experimental site. I am also grateful to the Soil Biology Department of Rothamsted Experimental Station for the use of their modified Tullgren extraction apparatus. This research was carried out under the tenure of a SERC CASE studentship with the Animal and Grassland Research Institute, Hurley, Maidenhead, Berks.

References

BAUHIN, G.K.A.; EDWARDS, C.A. (1964) The recolonisation of sterilised soil by invertebrates. *Report of the Rothamsted Experimental Station for 1963*, 149–150.

EDWARDS, C.A. (1977) Investigations into the influence of agricultural practice on soil invertebrates. *Annals of Applied Biology* **87**, 514–524.

EDWARDS, C.A.; LOFTY, J.R. (1975) The influence of cultivations on soil animal populations. In *Progress in Soil Zoology*, (Ed. J. Vanek). *Proceedings of the Fifth International Congress of Soil Zoology*, Prague, 1973, 399–408.

ELLIS, S.A.; BALE, J.S.; ATKINSON, H.J.; CLEMENTS, R.O. (1984) The influence of permanent pasture rejuvenation techniques and pesticide on the incidence of frit fly and yield. *Proceedings Crop Protection In Northern Britain 1984*, pp. 299–304.

RAW, F. (19598) Estimating earthworm populations by using formalin. *Nature London*, **184**, 1661–1661.

Effect of Soil-borne Pathogens on Ryegrass and White Clover Seedlings and their Control

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ABSTRACT

Glasshouse pot experiments indicated that soil-borne pathogens reduced emergence of perennial ryegrass seedlings by a third, but only in dry soil. In a micro-plot field experiment, sowing perennial ryegrass seed at 2.5 cm depth rather than 1 cm decreased emergence by a third, but the losses were only partly attributable to pathogens. In larger, drilled plots, herbage yield of perennial ryegrass was substantially, but not significantly increased by controlling soil-borne pathogens.

White clover seed was sown monthly, in micro-plots, from April to October, Controlling pathogens increased mean emergence over all sowings by 7% ($P<0.05$*).*

Fungicide seed treatment was an effective experimental tool for studying losses of perennial ryegrass seedlings, and offers an economical means of control. In pot experiments, seed treatments containing benomyl and/or captan gave excellent protection to perennial ryegrass, but not to white clover and treatments containing metalaxyl and/or iprodione benefitted neither species.

Introduction

Each year in the UK about 375000 ha of land are sown to grass or grass/legume mixtures, of which perennial ryegrass and white clover are the main components (ADAS 1983). The seed rate commonly used for perennial ryegrass is 20 kg ha^{-1}, or 1200 seeds m^{-2}, which is more than double the target seedling population for a satisfactory sward, and this target is not reached in many sowings (ADAS 1983). Recommendations for avoiding losses during sward establishment include good management and the control of pests and weeds (ADAS 1983), but the effects of soil-borne pathogens are seldom considered because their impact on seedling emergency has not been investigated comprehensively.

The main pathogen isolated from ungerminated seeds and dead seedlings of perennial ryegrass is *Fusarium culmorum* (Michail & Carr 1966), and it has been shown to greatly reduce emergence when perennial ryegrass seeds are sown in sterile soil re-infected with this fungus (Michail & Carr 1966; Holmes 1979). In this situation, seed treatment with the fungicides benomyl and captan provided excellent control (Holmes 1983), but in field sowings, no consistent responses to seed treatment were found (Holmes 1977). In New Zealand large responses to seed treatment have been reported (Falloon 1980) but the relevance of this work to the UK is not known. At present only about 1% of grass and fodder crop seed is treated with a fungicide (Hicks & Sly 1982).

Seedling mortality of perennial ryegrass has been shown to be greatest when seeds are sown deeply in warm, dry soil (Lewis & Lam 1983). This paper presents the results of experiments in the glasshouse and in the field to show the extent to which soil-borne pathogens are responsible for this mortality. Also, the impact of pathogens on white clover emergence was studied under different soil moisture levels.

Materials and Methods

CULTIVAR OF PERENNIAL RYEGRASS AND WHITE CLOVER

Perennial ryegrass cv. Parcour or white clover cv. Grasslands Huia was used in all experiments. Parcour was selected from a preliminary screening of 63 ryegrass cultivars as being possibly the most susceptible to soil-borne diseases although later work suggested that it was mid-range in susceptibility (G.C. Lewis, unpublished). Grasslands Huia was selected as the most widely sown white clover cultivar in the UK. Germination of untreated seed on moist filter paper in petri dishes was 95 and 100% for Parcour and Grasslands Huia respectively.

SOIL

All experiments used soil from one field at Hurley, which was of a sandy type.

FUNGICIDES

Fungicides used to treat seed were: benomyl (technical, 95% s.p., Du Pont Ltd), captan (Captan 83, 83% w.p., Murphy Chemical Ltd), metalaxyl (Apron 35 SD, 35% w.p., Ciba-Geigy Agrochemicals), and iprodione (Rovral WP 50, 50% w.p., May & Baker Ltd). Fungicides were applied by mixing with the seed in a plastic drum rotated at 60 rev/min for 5 min. Dose rates used in the experiments are given below.

Glasshouse Pot Experiments

EXPERIMENT 1. PERENNIAL RYEGRASS

Plastic pots of 14 cm diameter were filled to within 2 cm of the rim with sieved soil which was either sterilised by Cobalt 60 gamma-radiation, or unsterilised. The soil surface was flattened and 100 seeds/pot were broadcast over the surface and covered with soil to a depth of 2 cm. The soil surface was flattened again. A multi-factorial design was used, with seed treated with the fungicides benomyl, captan, metalaxyl and iprodione both separately and in all combinations, and untreated seed, sown in both sterilised and unsterilised soil. All 32 treatments were replicated twice and randomised.

The soil was watered sparingly after sowing and the glasshouse temperature was maintained at about 20°C (range 18–25°C). Numbers of seedlings emerging were recorded for each pot 15 days after sowing.

EXPERIMENT 2. PERENNIAL RYEGRASS

Experiment 1 was repeated using only unsterilised soil, and a glasshouse temperature of about 10°C (range 8–15°C). In 2 of the 4 pots used for each treatment the soil was watered sparingly and in the other 2 pots the soil was watered freely. Numbers of seedlings emerging were recorded for each pot 17 d after sowing.

EXPERIMENT 3. WHITE CLOVER

Experiment 3 was run concurrently with experiment 1, using the same layout, treatments and other details except that white clover seeds were used and were sown at a depth of 1 cm. Numbers of seedlings emerging were recorded for each pot 21 d after sowing.

Field Micro-plot Experiments

EXPERIMENT 4. PERENNIAL RYEGRASS

Micro-plots were sown on 1 July 1983 with 100 seeds/plot, 4 cm apart on a 10 × 10 grid pattern. The seeds were covered with sieved soil to a depth of either 1 or 2.5 cm and the soil surface was flattened. Four micro-plots were sown in each of 16 replicate blocks. Within each block, each plot was allocated at random one of four treatments: seed treated with benomyl + metalaxyl (each at a dose rate of 3 g a.i./kg seed) or untreated seed × sowing depth 1 or 2.5 cm. Numbers of seedlings emerging were recorded for each plot 46 d after sowing.

EXPERIMENT 5. WHITE CLOVER

Micro-plots were sown in 1984, on 5 April, 2 May, 6 June, 2 July, 1 August, 3 September and 8 October, using the same technique as in experiment 4 except that a single sowing depth of 1 cm was used. At each sowing, 2 plots were sown in each of eight replicate blocks, one plot being sown with seed treated with benomyl + captan (each at a dose rate of 3 g a.i./kg seed) and the other plot being sown with untreated seed. In 4 of the 8 blocks the soil had been protected from rainfall for 2 weeks before sowing and this continued for 2 weeks after sowing. The other 4 blocks were exposed to rainfall throughout. Number of seedlings emerging were recorded for each plot 20–76 d after sowing.

Drilled Plot Experiment

EXPERIMENT 6. PERENNIAL RYEGRASS

Plots, size 1.5 × 6 m, were sown on 5 September 1983 using an Oyjord precision drill. Two plots were sown in each of 6 replicate blocks; in one plot the seed was treated with benomyl + metalaxyl (each at a dose rate of 3 g a.i./kg seed) and in the other plot the seed was untreated. Tiller population was assessed 6 weeks after sowing by counting numbers of tillers in 30 cm lengths of drill row at 9 positions for each plot. Ten weeks after sowing the plots were cut and weighed using a Haldrup plot harvester and the dry matter content of the fresh herbage was obtained by drying a sub-sample of about 500 g.

Results

Glasshouse Pot Experiments

EXPERIMENT 1. EFFECT OF SOIL STERILISATION AND FUNGICIDE SEED TREATMENT ON EMERGENCE OF PERENNIAL RYEGRASS

Seed treatments containing benomyl and/or captan greatly increased emergence, whereas the others had either no effect or an adverse effect. Surprisingly, emergence from sterilised soil was 10% lower than from unsterilised soil ($P<0.001$) and there was no interaction between the soil and seed treatments. Therefore the results for the seed treatments shown in Table 1 are means of both sterilised and unsterilised soil.

Table 1: Emergence of perennial ryegrass cv. Parcour seedlings after sowing untreated seed and seed treated with four fungicides in all combinations (means of sterilised and unsterilised soil). Glasshouse temperature 20°C

	(% Emergence)							
	Captan				No captan			
	Metalaxyl		No metalaxyl		Metalaxyl		No metalaxyl	
	iprod-ione	no iprod-ione	iprod-ione	no iprod-ione	iprod-ione	no iprod-ione	iprod-ione	no iprod-ione
Benomyl	88.2	80.5	86.2	87.2	86.8	91.2	88.0	85.0
No benomyl	85.0	87.5	89.0	81.0	53.0	66.2	58.8	63.8
				s.e.d. =	5.05			

EXPERIMENT 2. EFFECT OF SOIL MOISTURE AND FUNGICIDE TREATMENT ON EMERGENCE OF PERENNIAL RYEGRASS

In dry soil, the emergence from untreated seed was 62.5% and some of the seed treatments containing either benomyl or captan greatly increased emergence (Table 2). In moist soil, the emergence from untreated seed was high (88.5%) and there was no effect of fungicide treatment. Mean emergence was 21% higher in moist soil than in dry soil ($P<0.001$).

EXPERIMENT 3. EFFECT OF FUNGICIDE SEED TREATMENT ON EMERGENCE OF WHITE CLOVER

Seed treatments containing benomyl decreased emergence by 14%, compared to treatments without benomyl ($P<0.05$). The other fungicides had no effect. Soil sterilisation decreased emergence by 27%, compared to unsterilised soil ($P<0.001$). Emergence from untreated seed in unsterilised soil was 65%.

Table 2: Emergence of perennial ryegrass cv. Parcour seedlings after sowing untreated seed and seed treated with four fungicides in all combinations. Soil watered sparingly and glasshouse temperature 10°C

(% Emergence)

	Captan				No captan			
	Metalaxyl		No metalaxyl		Metalaxyl		No metalaxyl	
	iprodione	no iprodione	iprodione	no iprodione	iprodione	no iprodione	iprodione	no iprodione
Benomyl	59.5	74.5	74.0	70.5	77.5	84.5	70.0	82.5
No benomyl	63.0	70.0	81.0	75.0	39.0	74.0	52.0	62.5

s.e.d. = 7.56

Field Micro-plot Experiments

EXPERIMENT 4. EFFECT OF DEPTH OF SOWING AND FUNGICIDE SEED TREATMENT ON EMERGENCE OF PERENNIAL RYEGRASS

Sowing at 1 cm depth increased emergence by 52%, compared with sowing at 2.5 cm ($P<0.001$). Seed treated with benomyl + metalaxyl increased emergence overall by 12% ($P<0.05$) and was equally effective at both sowing depths.

EXPERIMENT 5. EFFECT OF SOIL MOISTURE AND FUNGICIDE SEED TREATMENT ON EMERGENCE OF WHITE CLOVER AT SEVEN SOWINGS

Seed treatment with benomyl + captan increased the mean emergence over all 7 sowings by 7.2% ($P<0.05$), but had no significant effect at any individual sowing. Conversely, soil moisture had no effect on the mean emergence over all sowings, but at two individual sowings the covered plots had a significantly higher emergence and at another 2 sowings the exposed plots had a significantly higher emergence.

EXPERIMENT 6. EFFECT OF FUNGICIDE SEED TREATMENT ON TILLER POPULATIONS AND HERBAGE YIELD OF PERENNIAL RYEGRASS

Seed treatment with benomyl + metalaxyl increased tiller population and herbage yield by 14 and 96% respectively, but the increases were not significant.

Discussion and Conclusions

In dry soil, pathogens appeared to reduce the emergence of perennial ryegrass by up to a third. This was deduced from work in which fungicide seed treatment virtually eliminated the reduction in emergence found in dry soil. Mortality not attributable to pathogens was low in pot experiments, and emergence from treated seed often came close to the 95% germination rate achieved in petri dishes. The small difference that remained could have been due to the sowing depth used, 2 cm, which from the results of the micro-plot experiment, was likely to have reduced emergence. Fungicide seed treatment was a simple and effective tool for studying the effects of soil-borne pathogens and offers a practical solution to the problem.

Soil sterilisation by irradiation had an adverse effect on emergence of both grass and clover for some unknown reason, although it would seem that the soil had become re-infected because the results of fungicide treatment were similar in irradiated and natural soil. In earlier work, sterilisation by heat also affected emergence in some soils (Lewis & Clements 1982).

No attempt was made to identify the causal agent of seedling mortality but for perennial ryegrass there is strong circumstantial evidence that *Fusarium culmorum* was responsible. It was by far the most frequently isolated fungus from ungerminated seeds and dead seedlings in other studies on the same site (G.C. Lewis, unpublished). Dry soil had a large effect on emergence and this is known to increase the susceptibility of wheat seedlings to attack by *F. culmorum* (Colhoun & Park 1964). Finally, benomyl and captan were the most effective fungicides and a combination of these two provided excellent proection to perennial ryegrass seeds sown in soil artificially infected with *F. culmorum* (Holmes 1983). Treatment of white clover seed with benomyl + captan showed some benefit but the pathogenicity of *P. culmorum* and other soil fungi to white clover seedlings needs further investigation.

Sowing depth has a profound effect on grass emergence. Deeper sowing extends the period between germination and emergence and would be expected to increase the vulnerability of seedlings to fungal attack. However, the response to fungicide seed treatment was the same at both sowing depths used, and the likely explanation is that a proportion of the seeds sown did not have sufficient energy resources for the seedlings to reach the soil surface (Arnott 1969). Guidelines for establishing grass swards recommend that seed should be sown no deeper than 3 cm (ADAS 1983), but the present work suggests that in dry conditions sowing depth should be only 1 cm.

The results lend weight to the conclusion by Holmes (1983) that seed treatment with benomyl + captan is a simple and economic means of improving grass seedling emergence. Such treatment would cost only about 4 p/kg seed. The first attempt at improving emergence on a larger scale, using drilled plots, was encouraging, if not decisive. More recent work with drilled plots has sown that the benefits of fungicide seed treatment could be enhanced by the inclusion of an insecticide treatment (Lewis & Clements 1985). The effects on the environment of fungicide seed treatments are likely to be minimal. Further, since they enhance sward establishment, the need for subsequent herbicide treatment may be reduced.

Acknowledgement

The Animal and Grassland Research Institute is funded through the Agricultural and Food Research Council and the above work forms part of that done for a commission by the Ministry of Agriculture, Fisheries and Food.

References

AGRICULTURAL DEVELOPMENT AND ADVISORY SERVICE (1983) Sowing and establishing ryegrass swards. *Ministry of Agriculture, Fisheries and Food Booklet 2055*, 10pp.

ARNOTT, R.A. (1969) The effect of seed weight and depth of sowing on the emergence and early seedling growth of perennial ryegrass (*Lolium perenne*). *Journal of the British Grassland Society*, **24**, 104–110.

COLHOUN, J.; PARK, D. (1964) *Fusarium* diseases of cereals: 1. Infection of wheat plants, with particular reference to the effects of soil moisture and temperature on seedling infection. *Transactions of the British Mycological Society*, **47**, 559–572.

FALLOON, R.E. (1980) Seedling emergence responses in ryegrasses (*Lolium* spp.) to fungicide seed treatments. *New Zealand Journal of Agricultural Research*, **23**, 385–391.

HICKS, L.C.; SLY, J.M.A. (1979) Pesticide usage: Survey report 20, grassland and fodder crops. *Ministry of Agriculture, Fisheries and Food Reference Book 520*, 65pp.

HOLMES, S.J.I. (1977) Grass establishment problems and their control by seed treatments. *Proceedings of Symposium on Problems of Pest and Disease Control in a Northern Environment* pp. 7–8.

HOLMES, S.J.I. (1979) Effects of *Fusarium nivale* and *F. culmorum* on the establishment of four species of pasture grass. *Annals of Applied Biology*, **91**, 243–250.

HOLMES, S.J.I. (1983) The susceptibility of agricultural grasses to pre-emergence damage caused by *Fusarium culmorum* and its control by fungicide seed treatment. *Grass and Forage Science*, *38*, 209–214.

LEWIS, G.C.; CLEMENTS, R.L. (1982) Soil-borne fungi affecting grass establishment. *The Grassland Research Institute Annual Report for 1981*, p.53.

LEWIS, G.C.; CLEMENTS, R.O. (1985) Effect of fungicide seed treatment and post-emergence insecticide sprays on the establishment of Italian and perennial ryegrass. *Tests of Agrochemicals and Cultivars (supplement to Annals of Applied Biology)*, **6** (In press).

LEWIS, G.C.; LAM, A. (1983) Soil-borne diseases affecting grass seedling emergence. *The Grassland Research Institute Annual Report for 1982*, pp. 63–64.

MICHAIL, S.H.; CARR, A.J.H. (1966) Effect of seed treatment on establishment of grass seedlings. *Plant Pathology*, **15**, 60–64.

Discussion on Session 2 (R.O. Clements, Session Organiser)

Question Do any weed seedlings suffer from pest damage and if so, would the application of a pesticide protect them as well as protecting the crop?

Clements Some grass weeds would be prone to frit attack and an overall pesticide treatment may therefore benefit the weeds. However, a pesticide seed dressing which would be applied only to the crop would not have this disadvantage.

Question A comment rather than question. In several instances populations of frit fly larvae were low or absent, but responses to pesticide treatment still occurred.

Question Is damage by nematodes restricted to light-land, sandy soil types?

Spaull Not necessarily. Different combinations of nematode species and genera may be present on other soil types and could cause damage.

Saynor The threshold level for damage by nematodes may vary with soil type, perhaps because of differences in their water holding capacity leading to variations in stress on the seedlings.

Question Much of the work described has been done on small plots, but do the effects noted occur on a field scale?

Clements Yes, current field-scale work by AGRI confirms this.

Question Do any of the chemicals used, especially aldicarb, have a phyto-stimulatory effect?

Ellis In pot experiments very low rates of aldicarb had some effect, but rates used in the field had no effect.

Question Some pesticides may have an influence on crops by releasing soil nitrogen – how significant is this N effect?

Clements and other delegates The amount of nitrogen released in this way seems to be trivial and unimportant.