SESSION 4B

GRASS–WEED CONTROL STRATEGIES FOR BROAD-LEAVED CROPS

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INVITED PAPERS 4B-1 to 4B-6

GRASS-WEED CONTROL FOR BROAD-LEAVED CROPS - THE OPTIONS

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ABSTRACT

Safe, effective post-emergence graminicides and label recommendations for use in several broad-leaved crops offer new options for the farmer. Since their introduction, there has been a decline in use of pre-drilling treatments for annual and perennial grass weed control in oilseed rape, sugar beet, potatoes and peas. Surveys suggest that some areas were treated unnecessarily. Strategies are discussed for grass-weed control in arable broad-leaved crops including large scale vegetable crops grown within a cereal rotation in the UK. Where the rotation as a whole is considered, glyphosate, preferably pre-harvest of cereals, appears the most cost-effective means of eradicating perennial grass weeds.

INTRODUCTION

Trends in the UK have been towards more winter cereals, and these are sown earlier using reduced cultivations. The result has been an increase in the populations of grass weeds and volunteer cereals in broad-leaved crops in the arable rotation. As cereal prices fall however, there is an increasing interest in broad-leaved crops not only as breaks, but as alternatives. The EEC policy of support for oil and protein crops has meant that the UK areas of winter oilseed rape and peas harvested dry for animal feed have increased dramatically in the last few years.

A review of the control of grass weeds in broad-leaved crops was given by Jones and Orson (1982) but at that time none of the new post-emergence graminicides were Approved for use in the UK (MAFF 1982). There is an increasing number of options now available to the grower using new selective materials for post-emergence control or suppression of grass weeds in broad-leaved crops.

This paper aims to discuss justification for removal of grass weeds, the new options and their cost-effectiveness for the grower, changes in herbicide usage since they became available, and concentrates on strategies in arable broad-leaved crops including large scale vegetable crops grown within a cereal rotation in the UK.

GRASS-WEED SPECIES IN BROAD-LEAVED CROPS

Species of annual grass-weeds found in broad-leaved crops depend on time of sowing. In autumn sown oilseed rape, volunteer cereals are the most important as well as *Alopecurus myosuroides*, *Avena fatua*, and *Poa trivialis*. In spring sown crops of peas, sugar beet and carrots, volunteer cereals, *A. myosuroides* and *P. trivialis* are less likely to occur. There are few problems in early summer sowings of dwarf beans (*Phaseolus vulgaris*), and broad beans (*Vicia faba*). *Poa annua* occurs frequently in most crops but since it is susceptible to many pre-emergence residual herbicides used for broad-leaved weeds it is not a separate problem and therefore not discussed here. All broad-leaved crops may suffer infestations of Elymus repens and to a lesser extent Agrostis gigantea and Agrostis stolonifera and these are often not distinguished individually by the farmer, being referred to collectively as 'couch grass'. The current extent of the problem of grass weeds in broad-leaved crops is difficult to estimate.

The prospect of falling cereal prices will lead farmers to seek alternative crops. If, in the future, the area of broad-leaved crops increases, this would have the obvious effect of reducing grass-weed populations. Other factors such as the possibility of less stubble burning will aid survival of grass-weed seeds (Moss 1985), whereas straw incorporation should not affect the efficacy of post-emergence graminicides as it has some soil-applied herbicides used in cereals (Moss 1984). Changes in management techniques may influence grass-weed populations; for example, autumn preparation of sugar-beet seed beds may reduce grass-weed problems in spring.

BENEFITS OF GRASS-WEED REMOVAL IN BROAD-LEAVED CROPS

At present broad-leaved crops are not facing the same price restraints as cereals and it may not be quite so important to study cost of herbicides. Herbicides for control of grass weeds are usually more expensive than those for broad-leaved weeds, but for post-emergence annual grass-weed control yield responses of around 0.12 t/ha (4%) for winter oilseed rape, 0.2 t/ha (6%) for peas harvested dry, and 0.4 t/ha (1%) for onions are required to cover the direct cost of control. For perennial grasses the yield response required is 0.2 t/ha for oilseed rape, 0.33 t/ha for peas and 0.68 t/ha for onions. A distinction can be drawn between broad-leaved crops which suppress weed growth, such as oilseed rape, and those with less vigour which suffer proportionately more from weed competition, such as onions and carrots. Work by MacLeod and Rickard (1985) on cereal cover crops suggests that volunteer cereals are more likely to reduce yield in onions compared to sugar beet. No thresholds have been suggested for broad-leaved crops, above which spraying is likely to be worthwhile. Lutman (1984) found volunteer cereals at populations exceeding 70 plants/m² did not always reduce oilseed rape yields. In addition, there are penalties other than yield whose costs to the grower are difficult to quantify.

In crops harvested at dry seed stage, e.g. peas and field beans, green growth of E. repens hinders drying out, causes combining difficulties and may necessitate the use of a desiccant increasing production costs by about £20/ha. Grass weeds reduce harvesting rate and increase harvest losses. Delayed maturity can upset carefully planned vining pea harvest programmes involving expensive machinery and planned factory throughput.

There is often a premium for good quality and optimum size grade, e.g. for onions and carrots, and any check to growth from weed infestations (or chemical use) can be critical. (Shadbolt & Holm 1956) showed increasing weed competition caused progressive reduction in diameter of carrots, onions and red beet and that underground storage organs were the first part of the plant to be affected.

The long term effects of return of seeds of A. fatua and spread of E. repens in other crops in the rotation must also be considered, and depends on persistence of control from the various herbicides that are discussed later. Grass weeds within a broad-leaved crop have also been implicated in acting as a 'green bridge', carrying over diseases into the following crop, thus defeating the aim of a break crop in a cereal rotation. The main disease affecting a farmer's decision on cropping cereals, take-all (*Gaeumannomyces graminis*) is hosted by *E. repens* (Prew 1981).

The economic significance of all these factors is difficult to assess nationally, but must be attempted by the individual farmer.

NEW OPTIONS FOR GRASS-WEED CONTROL

(i) Post emergence graminicides

The post-emergence graminicide diclofop-methyl has been in use since 1978 and has shown selectivity in a large number of broad-leaved crops (as well as cereals). There are now label recommendations for 20 crops, including sugar-beet, brassicas, onions, carrots and lettuce. Limitations are that it will not control volunteer cereals, *P. annua* or perennial grasses.

A new generation of post-emergence graminicides selective in many broad-leaved crops has since been introduced. These control volunteer cereals and annual *and* perennial grasses. *P. annua* is not adequately controlled by these materials with one possible exception.

The first were alloxydim-sodium, sethoxydim and fluazifop-butyl. More recent introductions are quizalofop-ethyl, (Sakata *et al*. 1983), and haloxyfop-ethoxyethyl. The latter was used in sugar-beet trials and reported by Breay (1983) and found to have activity on *P. annua*. Cycloxidim (Zwick *et al*. 1985) is announced at this conference and there are other post-emergence graminicides under development. Eventually, there could be a very wide choice for the farmer.

Additives used with post-emergence graminicides

The effect of non-ionic surfactant and adjuvant oil additives on activity and selectivity of these graminicides has been studied. A leaf wetting surfactant was added in all experiments with fluazifop-butyl. Addition of adjuvant oil to alloxydim-sodium, and to sethoxydim showed enhanced activity and improved reliability of control of *E. repens* without causing phytotoxicity in sugar beet (Wilson & Munday 1983). In peas, the addition of oils may be damaging under some weather conditions particularly with alloxydim-sodium (Knott 1982). Performance of quizalofop-ethyl with non-ionic surfactant or mineral oil has been reported (Mayes *et al*. 1983, Rea *et al*. 1984). Oil appeared to give more reliable control of *E. repens* both during the crop season and the long term.

Tank mixes with broad-leaved herbicides

To allow for crop and weed recovery, time intervals between application of graminicides and another herbicide are specified on product labels and are seven days for diclofop-methyl, alloxydim-sodium, sethoxydim and fluazifop-P-butyl, and three days for quizalofop-ethyl. If safe, the latter may an have advantage because there are only 6 rather than 14 days when broad-leaved weeds may not be treated. This time interval may be crucial in a season with few spraying opportunities. In short season crops there may be insufficient time to safely apply two post-emergence sprays before crop growth stage becomes too advanced.

The target growth stage of broad-leaved and annual grass weeds frequently coincides. The possibility of tank mixing alloxydim-sodium and sethoxydim with broad-leaved herbicides has therefore been investigated in several crops including sugar beet (Wilson & Munday 1983), Fluazifop-butyl tank mixes were tested in sugar beet (Siddall & Cousins 1982). Quizalofop-ethyl tank-mixes were evaluated in sugar beet (Mayes et al. 1983) and oilseed rape (Rea et al. 1984). In most cases there were no detrimental effects to weed control or crop safety. Peas were an exception and tank-mixes were not selective (Knott 1982).

There are now recommendations for tank-mixes of alloxydim-sodium, or sethoxydim with some broad-leaved weed herbicides and this not only saves a pass with the sprayer but reduces risk of poor control where application is delayed.

In sugar beet, work is needed to assess low dose split applications of tank-mixes with broad-leaved herbicides. Evaluation of split applications of the new graminicides have shown control to be variable, sometimes better, sometimes worse than full rate (Knott 1982; Siddall & Cousins 1982, Sakata et al. 1983) and it is possible that the timing is having more effect than the rate applied. At the moment recommendations are to apply full recommended dose of graminicide in one application.

UK label recommendations

There are UK label recommendations (at the time of writing) for post-emergence graminicides in addition to diclofop-methyl, for :- alloxydim-sodium which also has Approval for use in most broad-leaved crops including vegetables; fluazifop-P-butyl (the herbicidally active isomer which replaces the two fluazifop-butyl isomers in the previous product) with wetter, has Approval for use in winter sown oilseed rape, sugar beet and fodder beet; sethoxydim with adjuvant oil has clearance for use in winter sown oilseed rape, sugar beet and limited clearance for use without oil in peas; quizalofop-ethyl with mineral oil has limited clearance for use in oilseed rape and sugar beet.

(ii) Application of glyphosate pre-harvest

Since 1974 the isopropylamine salt of glyphosate has been used commercially in the UK for control of *E. repens* and other perennial grass weeds in autumn cereal stubbles and on uncropped land. It has become the established standard for eradication. In 1980, the use of glyphosate pre-harvest of wheat and barley was introduced and this method ensures that the weeds are sprayed at a very susceptible growth stage (Friesen 1977). Further opportunities now exist for eradication of perennial grass weeds with glyphosate pre-harvest of some broad-leaved crops such as field beans and peas for harvesting dry (Knott 1983), oilseed rape and mustard. This gives benefit to succeeding crops and an earlier entry to winter wheat since the farmer does not have to wait for regrowth after harvest before treatment. Reduced rates and the addition of surfactants have been studied (Orson 1982) and have shown small loss of reliability at reduced cost where conditions were ideal for herbicide activity.

TIME OF GRASS WEED REMOVAL

The effect of time of removal of grass weeds on yield of broad-leaved crops depends on crop, weed species, environmental conditions and time of weed emergence in relation to the crop.

Annual Grasses

Information is limited, but for annual grasses, Ward (1982) suggested there was no consistent evidence to show early elimination in winter oilseed rape with pre-drilling or pre-emergence herbicides leads to higher yields, and Lutman & Dixon (1985) and Orson (1984) investigating volunteer cereals, supported this view, except in the case of late sown crops of poor vigour. Experience has shown that the best results with the new post-emergence graminicides are achieved when applied at full emergence of annual grasses, and lower than recommended dose rates can be used if the majority are at the two to four leaf stage and growing conditions are good. In spring sown crops timing is about mid May for annual grass weeds and since the effect is rapid, this should prevent competition. It appears that early application of post-emergence graminicides to remove annual grasses before the period of rapid crop growth is an acceptable alternative to pre-drilling or pre-emergence treatments.

In most commercial crops it is probable that populations of A. fatua are at a low uncompetitive level and, unless re-seeding is likely, the best decision may be not to spray. The use of pre-drilling and pre-emergence applications is based on assumptions of infestations of annual grasses and farmers tend to take a cautious (or pessimistic) view.

Perennial Grasses

Applications of post-emergence graminicides to perennial grasses, E. repens for example, must be made when the weed is actively growing. Under cold or drought conditions where growth is slow, speed of action and efficacy will be reduced. The optimum target is at four leaf to early shoot extension stage, which usually occurs in early June, late in the life of some spring sown crops such as peas, carrots and onions. Although weed growth appears to cease soon after application of post-emergence graminicide and three to four weeks sees complete foliar kill, removal of competition only a few weeks before harvest may be too late to maximise yield.

SUPPRESSION VERSUS ERADICATION

Farmers usually look for control of E. repens and other perennial grasses which extends beyond the current crop season. Work with post-emergence graminicides on persistence of control in succeeding crops is limited. Atkin and Wilson (1980) suggested that alloxydim-sodium will not eradicate E. repens but will contain infestations for two seasons. Siddall and Cousins (1982 and 1983) showed alloxydim-sodium and fluazifop-butyl applications in sugar beet reduced shoot numbers of E. repens by approximately 70% in the following spring barley crop. Assessments post-harvest of oilseed rape showed continued suppression of regrowth from applications of quizalofop-ethyl in November of the previous year (Rea et al. 1983). Davies and Richards (1984) found that the effect on E. repens of alloxydim-sodium, fluazifop-butyl and sethoxydim applied in potato crops persisted into the following season. Continued suppression of perennial grasses will depend on the competitive nature of the following crop.

This data suggests that the post-emergence graminicides may offer more persistent control than initially thought, but the kill of all rhizomes buds is essential if E. repens is to be eradicated and for the moment it is perhaps safer to assume that glyphosate, with proven efficacy, offers the best means of control until more long term evaluation assessments have been completed. Glyphosate costs slightly less, and also controls many broad-leaved perennial weeds.

GRASS WEED CONTROL IN SPECIFIC BROAD-LEAVED CROPS

Surveys for herbicide useage provide information on management practise and changes in approach to a problem in specific crops. Provisional figures for the UK area for 1985 are given (MAFF 1985).

Oilseed Rape (296 thousand ha)
Surveys for the 1982 crop (Bird & Sly 1984, Jeffrey *et al*. 1983) show usage of TCA prior to drilling was the most important to control volunteer cereals (the main problem) and grasses. TCA is often incorporated just before drilling, but for perennial grasses a time interval and a higher rate is required. Results are less reliable under dry conditions and there is concern about the tolerance of oilseed rape. The surveys also show 0.9% of the area was treated with alloxydim-sodium. Management has since changed to significant increases in use of post-emergence graminicides for volunteer cereals and grass weeds (13% of the 1983 crop, 35% for 1984) with a decline in use of pre-drilling grass-weed herbicides from 99% of the oilseed rape area for 1982, to 82% for 1983, 45% for 1984 and 28% for 1985 (Farmstat 1985). The total area treated for grass weeds has decreased slightly, presumably because use of post-emergence materials allows the severity of the problem to be assessed before spraying and spot treatment applied.

For *E. repens* control, glyphosate is now being used pre-harvest of the preceding cereal so there is no delay in drilling whilst waiting for grass regrowth, and also pre-harvest of oilseed rape.

Sugar Beet (206 thousand ha)
Sugar beet is discussed elsewhere in this session (Breay 1985). He says that in the past the farmer has relied on tri-allate for control of annual, and TCA for perennial grasses, but is now well served with post-emergence herbicides. There is a swing away from pre-drilling incorporated treatments because they are detrimental to seedbeds.

Surveys (Farmstat 1985) show total crop area treated pre-drilling and post-emergence for grass weeds was 42% in 1981, 30% in 1982, 27% in 1983 and 22% in 1984, i.e. there was no corresponding increased usage post-emergence, where pre-drilling treatments were not applied. Thus a 'wait and see' policy paid off, and in the past treatments may have been used unnecessarily.

Potatoes (191 thousand ha)
Glyphosate is used to control perennial weeds, mainly *E. repens* in the previous autumn. Of the 1980 crop, 3% was also treated with EPTC mainly for control of *E. repens* (PMB 1980). Farmstat surveys since then show a decrease in usage of this material, which requires incorporation to 15 cm depth after application to ensure satisfactory control. EPTC is useful where glyphosate treatment in autumn is not possible, mainly where potatoes are grown on rented land. In some areas stone separators are used, and the *E. repens* growing in stone windrows is better controlled with a post-emergence graminicide than EPTC. This option has been taken up, although for the moment only alloxydim-sodium has clearance for use in potatoes. Farmstat Surveys (Farmstat 1985) show a trend towards a reduction in use of pre-planting treatments and corresponding increase in use of a post-emergence graminicide.

Materials are rarely used specifically for A. fatua and annual grasses are normally controlled by application of contact sprays of paraquat pre-emergence, or with tank mix of paraquat with a residual broad-leaved weed killer which may also give some control of Poa annua and other annual grasses. The use of cultivations is declining and reflects the awareness of risk of damage to growing plants.

Peas

The provisional figure for peas harvested dry for animal feed shows the UK area has increased to 77.7 thousand ha (MAFF 1985) and in addition about 14 thousand ha are grown for human consumption. The area of vining peas harvested at the green immature stage for quick-freezing and canning was 46 thousand ha in 1984.

Before safe post-emergence graminicides became available control of A. fatua was mainly with tri-allate applied pre-drilling and incorporated. Tri-allate in granular form pre-drilling or pre-emergence is another alternative less frequently used. For 1983 and 1984 there appears to be a trend towards a reduction in use of pre-sowing treatments (Farmstat 1985), with post-emergence diclofop-methyl or alloxydim-sodium applied where needed, i.e. there is not a corresponding increase in post-emergence use. This would imply that 'blanket' treatments may sometimes be used unnecessarily.

Perennial grasses affect a smaller proportion of the crop than annual grasses. TCA is seldom used now. Usage of glyphosate for eradication of E. repens either pre-harvest in cereals, or in the autumn before sowing peas is increasing, but is not often possible where the vining crop is grown on rented land. Since 1983, use pre-harvest of dried peas is another option.

Field Beans (45.5 thousand ha)

The crop is mainly winter sown, often on heavy soils unsuitable for spring drilling or growing peas. These areas frequently suffer from infestation with E. repens but figures from the Pesticide Usage Survey for England and Wales, 1982 (Sly 1984), show only 6% of the crop was treated with glyphosate the autumn before sowing. The new recommendation for glyphosate pre-harvest of beans is particularly useful in that the opportunity for application to autumn regrowth of E. repens is limited after a late harvested bean crop.

Simazine is widely used pre-emergence for general weed control (47% of the area in 1982), although in practice inadequate drilling depth reduces the safety margin for the crop. It will give some control of annual grasses A. fatua, A. myosuroides and P. annua and volunteer cereals. Pre-drilling treatments are little used owing to the difficulty of incorporation on heavy wet soils. A small area is treated post-emergence. Only alloxydim-sodium has clearance and a label recommendation for post-emergence suppression of perennial, and control of annual grasses in field beans.

Forage & Fodder Brassicas (fodder rape, kale, swede, turnip, fodder beet & mangolds) (109.8 thousand ha)

Perennial grasses are considered the main problem. The survey for 1982 (Sly 1984) indicated a change to the use of glyphosate in autumn before sowing turnips, swede, kale and fodder rape, to eradicate E. repens, whereas previously TCA was used.

There are now label recommendations and Approval for alloxydim-sodium in all these crops and for fluazifop-P-butyl in fodder beet only. Lawson and Wiseman (1982) suggested that some brassicas were not very tolerant of some post-emergence graminicides.

Other Vegetable Crops in Arable Rotations (88 thousand ha in 1984)

The area has declined in the last few years and the cost of vegetable production is high in the absence of overall market support. There are fewer intensive vegetable enterprises where grass weeds are not normally a problem, and most vegetables are a farm crop grown as a 'break' in cereal rotation and may be infested with volunteer cereals and annual and perennial grass weeds. A review of Usage of Pesticides in Agricultural and Horticultural Crops in England and Wales 1980-83 (Sly 1985) show about 20% of vegetables (including vining peas) and bulbs are treated specifically for grass weeds.

Glyphosate application pre-harvest of cereals or in autumn is now used for control of E. repens in preference to TCA. Prior to 1982, the only label recommendation for post-emergence suppression of E. repens in vegetable crops was for dalapon in carrots, and this was not always reliable. Where row width allowed, as in brussels sprouts for example, cultivations were the only means of post-emergence treatment. Now alloxydim-sodium is proving extremely useful for suppression of perennial grasses in many vegetable crops. As yet there is no clearance through the PSPS for other new post-emergence graminicides.

In the survey, tri-allate, with label recommendations for most vegetables, was the most widely used material for annual grass-weed control. Diclofop-methyl may be used to control A. fatua post-emergence. Neither controls volunteer cereals. Alloxydim-sodium now solves this problem and is useful for over-wintering onions sown in summer after cereals where there is insufficient time to allow pre-drilling treatment. Where spring sown onions or carrots are provided with a windbreak of cereals to prevent crop damage from soil erosion, the post-emergence graminicide gives a rapid kill to allow continuation of shelter but not competition.

Vegetables grown on rented land, carrots and brassicas in particular, may be affected with unexpected infestations of annual grasses, autumn treatment may not be applied to eradicate E. repens and there may be insufficient time pre-drilling to use TCA or dalapon. Here, a post-emergence graminicide can retrieve the situation.

To sum up:

Herbicide usage surveys have shown a decline in use of pre-drilling treatments in oilseed rape, sugar beet, potatoes and peas for annual and perennial grasses since the introduction of effective, safe, post-emergence graminicides. Although pre-drilling herbicides (excluding incorporation costs) are about 40% cheaper for annual and perennial grass-weed control than post-emergence graminicide treatments at appropriate rate, application is made to the whole field to an unknown level of infestation. Post-emergence graminicide options have rapidly been taken up and allow farmers to spot treat infested areas, and save costs. Since there was no corresponding increased use of post-emergence treatments, i.e. total area treated was less in sugar beet and peas, and slightly less in oilseed rape, this implies that a 'wait and see' policy is cost effective and in the past treatments have been used unnecessarily.

The use of TCA pre-drilling removes grass weeds before they compete with the crop but is not satisfactory because control is not always reliable, particularly under dry soil conditions; margin of safety is low; soil incorporation is required and this may cause soil compaction which is detrimental to the seed bed; drilling may be delayed where incorporation is not possible in wet conditions or where a few weeks time interval is required between application and sowing.

Tri-allate applied pre-drilling and incorporated has been used for successful control of annual grasses in UK crops for more than 20 years. It is safe, the weeds are removed before they emerge, and the residual activity solves the problem of control where grasses germinate over a long period. Tank mixes with herbicides for broad-leaved weeds are used in some crops. However, there are potential problems with soil compaction. New techniques for easier incorporation reducing the number of wheelings are now recommended by the manufacturer. Tri-allate applied in granular form pre-drilling or pre-emergence with only light incorporation is another alternative, but soil moisture is needed after application.

EPTC is very effectively used against E. repens, pre-planting in potatoes. However, the cost is similar to glyphosate and incorporation into a good seedbed is required.

Farmers are now eradicating perennial grasses by application of glyphosate pre-harvest in cereals, in the autumn (now usually included in surveys, although easily forgotten by farmers), or using new opportunities offered pre-harvest in oilseed rape, field beans and peas harvested dry.

CONCLUSIONS

Given the new options for grass-weed control, the problem is deciding when and where to use them. Cost-effective stategies must be derived for the benefit of the whole farm rotation, bearing in mind that in broad-leaved crops, particularly vegetables, the effect of grass weeds on quality and harvestability as well as yield must be considered. Strategy will vary with weed and crop.

Annual Grasses, Volunteer Cereals and Shelter Crops

P. annua is not controlled by the new post-emergence graminicides but fortunately is susceptible to many standard pre-emergence herbicides for broad-leaved weeds and is rarely considered as a separate case for control.

(i) Pre-sowing application of tri-allate is still appropriate where soil conditions are suitable for incorporation and infestations likely to be severe for A. fatua and other annual grasses including P. annua, but with the exception of volunteer cereals.

(ii) Post-emergence graminicides are the best means of control in many instances since grass-weed populations and their competitiveness can be assessed before spraying and spot treatment where possible will reduce herbicide cost. Populations of A. fatua in the UK are often at a low level. To aid decision-making it would help the farmer to know what threshold infestations are likely to cause loss of yield or quality and affect harvestability in various crops. So far there is little information. A major factor for consideration is whether A. fatua is likely to re-seed or not, and in early harvested crops this is less probable.

Diclofop-methyl, used commercially since 1978, is safe in most broad-leaved crops, effective on A. fatua and several other annual grasses, but will not control volunteer cereals or P. annua.

Efficacy of newer post-emergence graminicides has now been proved in trials and commercial use for a wide range of annual grasses (except P. annua) including volunteer cereals. They are tolerated in many broad-leaved crops. There are now recommendations for alloxydim-sodium, sethoxydim, fluazifop-P-butyl and quizalofop-ethyl in sugar beet and winter oilseed rape. Only alloxydim-sodium has a recommendation for potatoes and several vegetable crops. The grass weeds must be fully emerged, and growth must be active. In practice, emergence is often prolonged, and different species may emerge at different times. Information suggests that annual grass weeds can be controlled post-emergence before they become too damaging to crop development, with the exception of onions.

There are recommendations for tank mixtures with herbicides for broad-leaved weeds for some crops where optimum target stages for both are likely to coincide. Otherwise time intervals of three, seven or more days must be left between applications and this may be at the expense of broad-leaved weed control. Under these circumstances a pre-emergence herbicide for broad-leaved weeds should be used where possible.

These new options for control of volunteer cereals, the main grass weed problem of winter oilseed rape, have rapidly been taken up. Cereal shelter crops sown to prevent damage to onions and sugar beet caused by soil erosion (and grass weeds present at the time of spraying) can be destroyed using post-emergence graminicides.

Perennial Grasses

(i) Where the rotation as a whole is the main consideration, the best plan is to eradicate perennial grasses from the farm by the most effective means, application of glyphosate to the actively growing weed, preferably pre-harvest of wheat or barley. When used pre-harvest of other crops the weed has already had a chance to act as a 'green bridge'. Although traditionally broad-leaved crops are regarded as cleaning crops, pre-harvest of cereals may well become the place for eradication of many perennial weeds. At the maximum recommended rate for glyphosate of 1.44 kg a.e./ha, cost is less than for post-emergence graminicide treatment, similar to EPTC used in potatoes, but is 30% more than TCA. There are recommendations for lower rates of 1.08 kg a.e./ha glyphosate for E. repens infestations of less than 75 shoot/m². Glyphosate has the added advantage of cleaning up other perennial weeds, and volunteer potatoes.

(ii) The new post-emergence graminicides, fluazifop-P-butyl, sethoxydim and quizalofop-ethyl have recommendations for control of E. repens in sugar beet and winter oilseed rape, alloxydim-sodium for suppression in several broad-leaved crops. The means of post-emergence control has already been of great individual value to growers of vegetables such as onions, peas and carrots where previous recommendations were non-existent or damaging. The new materials also offer a means of suppression of E. repens on rented or recently acquired land. Annual grasses present will also be controlled at the high rate.

The timing for application of post-emergence graminicides at optimum target growth stage of E. repens is later than for annual grasses in spring sown crops and may be too late to prevent competition and yield reduction. Timing is very important and although these materials are more consistent in activity than TCA, their efficacy is reduced under slow growing conditions. Extended control is sought, and although the new graminicides suppress top growth of perennial grasses in the current season and continued suppression may be possible with a following cereal crop, more long term assessment of persistence of control is needed.

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CONTROLLING GRASS WEEDS FOR SUGAR BEET

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ABSTRACT

This paper examines opportunities for controlling grass weeds for sugar beet.
Glyphosate used pre-cereal harvest is an effective treatment against perennial grasses.
In dry seasons when glyphosate may produce unsatisfactory results either stubble cultivation to desiccate these weeds or selective post-emergence graminicides should be considered as alternative treatments.
Pre-drilling, soil-incorporated herbicides make the adoption of better cultivation techniques difficult to put into practice and their use is declining.
Selective post-emergence graminicides allow improved cultivation techniques and are cost effective especially where annual and perennial grass weeds occur together.

INTRODUCTION

This paper is not intended to be a detailed report on results from herbicide trials but reviews and summarises the current "state of the art" with regard to grass-weed control for sugar beet. The opportunities for grass weed control for sugar beet are discussed in the following chronological order.

1. Pre-cereal harvest prior to beet.
2. Control in the autumn.
3. Pre-drilling of beet.
4. Post-emergence of beet.

For each of these categories relevant experimental and survey data indicating current uses and points for and against their continued use are discussed in the following section.

RESULTS AND DISCUSSION

1. Pre-cereal harvest

The control of perennial grass and broad-leaved weeds pre-cereal harvest using glyphosate to achieve long term control (O'Keeffe 1980) has both advantages and risks (Orson 1982). However if the conditions where poor performance is likely to occur are appreciated then appropriate alternative control measures can be used.

The main advantages of using glyphosate pre-cereal harvest are:

1. Perennial grass weeds are at their most susceptible growth stage (Friesen 1977, Cussans 1968).
2. A wide range of weeds are controlled (O'Keeffe 1980).
3. The risk of weed competition is removed before beet is sown.
4. The need for subsequent repeated cultivation (Cussans 1968) in an attempt to control perennial grass weeds is avoided. Such cultivations can seriously affect seedbed quality if carried out after ploughing.

5. It may improve the harvestability of the cereal crop (O'Keeffe 1981, Sheppard et al. 1982).

Conversely the risks involved with pre-cereal harvest glyphosate are :

a) That drought stress may cause cessation of weed growth or weed senescence and under these conditions pre-cereal harvest glyphosate may prove unreliable (Orson 1982). In this situation alternative methods of control should be considered.
b) Rain falling immediately after treatment will wash glyphosate off the weeds resulting in poor control.
c) Conditions might be unsuitable for spraying pre-harvest due to poor weather and/or poor soil conditions.

2. Control in the autumn

The control of perennial grasses by cultivation is a traditional technique which still deserves consideration. Exhaustion of rhizomes/stolons by cultivation can be a cost effective way to control these weeds in a dry autumn. If the soil is too wet at this time then cultivations are unlikely to produce satisfactory results. Wet conditions favour new weed growth and once new growth has appeared, spraying glyphosate is more likely to produce a commercially acceptable result. The success of cultivations as a treatment is also affected by soil type, heavy soils being much more difficult and expensive to work down to a tilth which will dry out sufficiently to exhaust the rhizomes.

A simple comparison of costs between spraying glyphosate and cultivation (Table 1) makes interesting reading.

TABLE 1

Comparison of costs between chemical and cultivation techniques for perennial grass weed control.

	Total Cost £/ha
Chemical technique	
glyphosate 4 l/ha product @ £15.30/l (1985 RRP) + £4.40* for spraying operation	65.60
glyphosate 2 l/ha product @ £15.30/l (1985 RRP) + £4.40* for spraying operation	35.00
Cultivation technique	
3 passes with chisel plough first pass £12* + 2 passes @ £9 each*	30.60

* Source Nix (1985)

The 2 l/ha product rate of glyphosate is likely to produce reliable results when the soil is damp and weed growth active so these two control measures compare well in terms of cost/ha treated, each performing best under different weather conditions.

3. Pre-drilling of beet

Annual grass weeds

Until 1980, when alloxydim-sodium was introduced for post-emergence control of grass weeds, beet growers had to rely on soil-incorporated tri-allate di- allate or cycloate to control annual grass weeds. Following the introduction of alloxydim-sodium, three additional herbicides, fluazifop-P-butyl, sethoxydim and quizalofop-ethyl were produced. Their development and high degree of efficiency in controlling *Avena fatua* (Breay 1983) and *Alopecurus myosuroides*, has resulted in a rapid decline in the use of pre-drilling soil-incorporated herbicides for grass weed control (Fig. 1).

Fig. 1.

1. Pre-drilling herbicide usage expressed as a % of area grown.

Fig. 1. Pre-drilling herbicide usage expressed as a % of area grown.
10% of the sugar beet area = approximately 20000 ha.
Fig. 1 does not include pre-harvest or stubble glyphosate.

This decline in use of pre-drilling, soil-incorporated herbicides is likely to continue and is being encouraged by British Sugar advisers. The main reason for this is because the application and incorporation of these products leads to extra tractor traffic across seedbeds prior to drilling. This can cause excessive soil compaction and drying out of the seedbed which results in poor establishment, poor summer growth and consequently lower yields (Breay 1982).

At present there are only limited trial data to support this comment but the visual effects of excessive cultivation and wheel compaction in commercial crops are obvious.

A second reason why pre-drilling, soil-incorporated herbicides may not be cost effective is that the problem has to be anticipated before it is visible and therefore treatment may not always have been necessary. Thirdly, with herbicides like cycloate and lenacil applied as a tank mixture, there was always a risk of crop damage on light soils, unless the application rate was precise and subsequent post-emergence treatments for broad-leaved weed control were carefully chosen by the farmer (Hilton & May 1985). Fig. 1 shows that by 1985 cycloate usage had ceased.

Perennial grass weeds

Fig. 1 shows that 4% of the sugar-beet crop had TCA applied pre-drilling in 1981 and that this declined to less than 1% in 1985. Before the introduction of post-emergence graminicides, TCA was used principally to control perennial grasses but where present, annual grasses were also controlled. TCA is known to have an effect on crop establishment and seedling vigour (Bray & Hilton 1975), although statistically significant reductions in yield were difficult to measure. TCA is recommended to be used soil-incorporated, pre-drilling and this factor, plus the effects on early crop vigour, have led advisers to discourage its use. Less than 2000 ha of sugar beet are now sprayed with TCA and it is expected that this usage will cease within two years.

4. POST-EMERGENCE CONTROL

The availability of effective post-emergence herbicides to control grass weeds in sugar beet has meant that the whole strategy for cultivating sugar beet can be re-arranged to the advantage of the crop, rather than being dictated by the requirements of the herbicides which have previously been used to control these weeds on approximately 30% of the crop. In 1984, 8% of the sugar-beet crop was treated with a post-emergence graminicide for either perennial or annual grass weeds (British Sugar 1984). This data does not show treatment against specific weeds but it must be assumed that the greatest use of these graminicides is to control annual grasses, considering the reduced area sprayed with tri-allate.

In trials, post-emergence graminicides have demonstrated a high degree of efficiency; often 99% control or more (Breay 1983) against annual grass weeds, providing the treatment is correctly timed. Subsequent developments and commercial pressures have shown that dose rates lower than those originally tested are efficient, so now there is little difference in cost between soil-incorporated tri-allate and a post-emergence graminicide.

TABLE 2

Cost comparison between pre-drilling, soil-incorporated tri-allate and post-emergence fluazifop-P-butyl.

	£/ha
Tri-allate	
4 litre product/ha @ £5/litre.	20.00
Soil-incorporation, + one additional pass with a harrow.	3.50*
	23.50
Fluazifop-P-butyl 1 litre product/ha	25.00

* Source Nix (1985)

Since both products are sprayed, the cost of application has not been included.

Table 2 shows that the difference between the two types of treatment is small, £1.50/ha, in favour of a soil-incorporated spray. The ability to see the problem and the opportunity to avoid the additional harmful effects of wheel compaction created while applying and incorporating herbicides pre-drilling, makes post-emergence treatment of annual grass an attractive proposition from a commercial point of view. One grass weed which is not well controlled by post-emergence graminicides is Poa annua. However, this grass performs more like a broad-leaved weed in that P. annua is normally well controlled by herbicides applied to control broad-leaved weeds.

Perennial grasses.

The case for post-emergence control of perennial grasses is more difficult to argue because under favourable conditions the planned use of pre-cereal harvest glyphosate is so efficient. However, there is one situation where a post-emergence herbicide has to be used (i), one where it should be used (ii) and one possible development for the future (iii).

(i) The unexpected appearance of perennial grass weeds in the crop. Weeds which appear to be insignificant in the crop prior to beet suddenly develop into a serious problem in the sugar-beet crop.

(ii) Where both an annual and perennial grass weed problem is anticipated, the rate of post-emergence herbicide used to control the perennial weed problem is more than adequate to control annual grasses, so in this situation, tri-allate used pre-drilling would be a waste of money because it will not control perennial grasses.

(iii) In the future it may be possible to develop post-emergence graminicides to give reliable long term control of perennial grasses. Although all the post-emergence herbicides currently available have performed well in British Sugar trials, occasionally and unpredictably, one of these products in a trial situation will fail to give satisfactory control. This is because of regrowth around the point of the originally treated aerial shoot. When this occurs, long term control cannot be expected but by understanding what happens in this situation, it should be possible to design a treatment strategy to prevent regrowth.

In British Sugar trial fields, observations on the growth of perennial grass weeds in farmers' crops alongside trials have shown that better season-long control can be achieved when an inter-row cultivation is carried out 10-14 days after spraying graminicide. In this situation, it appears that the cultivation treatment is destroying the majority of surviving buds on rhizomes and stolons but obviously this treatment will not solve the problem of regrowth in the row. The conclusion seems to be that a repeated chemical treatment would be successful in controlling this regrowth.

More work is required to test this conclusion and to establish cost effective dose rates for a split application regime. Using a split application regime to control perennial grass weeds should allow the first application to be timed earlier. This reduces the risk of weed competition and increases the time during which regrowth can occur before sugar beet leaves shade the remaining weeds. To be successful, correct timing of treatments is crucial, especially if the objective is long term control. Correct timing is also important for the successful control of annual grass weeds because by spraying too early, late emerging weeds escape and by spraying too late, heavy populations of these weeds will compete strongly with the crop, resulting in loss of yield. Early results from British Sugar trials testing the competitive effect of annual grass weeds, which are left for post-emergence control, suggest that this factor is particularly important on sandy soils.

In conclusion, a strategy for annual grass weed control in sugar beet should employ post-emergence graminicides to support a cultivation technique which minimises tractor traffic between ploughing and drilling. Applications of fertiliser and pesticide can be managed to avoid this traffic between ploughing and drilling which leaves the farmer free to concentrate on seedbed preparation.

The efficient control of perennial grass weeds is most likely to be achieved using glyphosate which will also control perennial broad-leaved weeds. Under conditions of drought stress and weed senescence, when glyphosate may not produce reliable results, either stubble cultivation or post-emergence graminicides should be considered as alternative methods of control.

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EFFECTS OF CEREAL COVER CROP AND PLANTED STRAW ON YIELD OF ONIONS AND SUGAR BEET

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ABSTRACT

Three trials on spring sown onions and two on sugar beet were conducted on a ploughed and cultivated soil sensitive to wind erosion. A non-sheltered control was compared with a live cereal cover crop subsequently killed by application of a graminicide or with the use of inter-row planted straw to provide an inert shelter. The trials were conducted in the absence of severe wind damage and have measured the effect of the different crop shelter systems on yield and other relevant crop characteristics. For onions, where there is a risk of wind damage every year, inter-row straw has been effective. Inter-row barley has caused crop competition where killing off was delayed and has resulted in reduced yields. With sugar beet the risk of wind damage is lower and the use of a live cover crop has been an attractive system.

INTRODUCTION

Crops such as sugar beet and onions, both grown widely on the organic peat soils of the Fenland basin of Eastern England, are vulnerable to soil erosion by wind. Various estimates of frequency of occurrence of such wind damage have been made and this incidence is affected by local agronomic conditions as well as by climatic and soil factors. However, at the Arthur Rickwood EHF we can, based on past records, expect significant crop loss in onions on 14 occasions in 10 years, and in sugar beet on 6 occasions in 10 years. A small seeded crop like onions sown into a fine seedbed in late February may not emerge until early April and does not achieve sufficient ground cover to be self-protecting until mid June, giving a risk period of around 14 weeks. With sugar beet, drilling is later and growth more rapid giving a risk period of around eight weeks.

In 1982 two series of trials were initiated at the Arthur Rickwood EHF comparing straw planting between the crop rows, cereals as a live cover crop controlled with alloxydim-sodium in onions or fluazifop-p-butyl in sugar beet, and a non-sheltered control. These trials were continued until 1984 and are reported in this paper.

MATERIALS AND METHOD

Soils

These trials have been conducted on peaty loam or loamy amorphous peat soils varying in depth from 30 to 60 cm and belonging to the Adventurers or Prickwillow series. A pH of 6.0 is maintained within plough depth by liming and organic matter levels range from 23 to 37%

Onions

In 1982, 1983 and 1984 the following treatments were compared on plots precision drilled to a stand with a Stanhay drill following autumn ploughing and conventional spring cultivations:-

1. Control - no shelter.
2. Inter-row planted straw.
3. Inter-row cereals - early kill.
4. Inter-row cereals - late kill.
5. Inter-row transplanted onions - as multiplant modules.

In each year the onion crop (cv Balstora) was drilled in five rows spaced 350, 200, 200, 350 mm across 1.68 m beds leaving room for shelter treatments in the two wider inter-rows and therefore spaced at 750 mm centres. The inter-row straw was planted mechanically to produce a barrier 15 cm high. The transplanted onions were raised in Hassy trays and were also established in the two wider rows at 750 mm centres of appropriate plots. The cereal shelter treatments were sprayed off using a CO_2 operated Oxford Precision Sprayer. In 1982 1.87 kg a.i./ha of alloxydim-sodium was applied in 300 l/ha water through a Spraying Systems 8001 'TeeJet' at 210 kPa spray pressure. In 1984 1.75 kg a.i./ha alloxydim-sodium was similarly applied but in a spray volume of 200 l/ha. However in 1983 0.72 kg a.i./ha glyphosate in 200 l/ha as a shielded spray was the treatment used to kill the cereals. The 1982 and 1984 trials were 5 x 5 latin squares and the 1983 one was a randomised block with six replications. Other treatment details and dates are listed in Table 1.

TABLE 1

Diary for onion experiments

	1982	1983	1984
Cereal shelter	Oats (cv Maris Quest)	Barley (cv Triumph)	Barley (cv Triumph)
Onions drilled	16 February	8 March	23 February
Cereal drilled	23 February	15 March	9 March
Straw planted	1 April	18 March	8 March
Onions planted	1 April	7 April	5 April
Cereals sprayed (early)	7 May (GS 30)	18 May (GS 24)	21 May (GS 25)
" " (late)	18 May (GS 39)	24 May (GS 30)	4 June (GS 30)

Sugar Beet

In 1983 and 1984 the following treatments were compared which were precision drilled to a stand with sugar beet following autumn ploughing and conventional cultivations:-

1. Control - no shelter.
2. Early sown broadcast barley.
3. Late sown broadcast barley.
4. Inter-row straw planted before crop emergence.

In both years the trial was conducted as a 4 x 4 latin square with plots 30 m square.

The sugar beet was cv Monoire and the spring barley shelter cv Triumph. The barley was broadcast at 50 kg/ha across the intended sugar beet rows on two different dates before drilling, a Nordsten drill with the coulters removed was used. The beet was precision drilled in 56 cm rows and 1.75 cm spacings. The plots were drilled with a five unit Stanhay drill with the three central rows under the tractor. The inter-row straw was subsequently mechanically planted on either side of the central row using the same wheelings to give two rows of straw in each set of five rows of sugar beet across the plot and producing a barrier 15 cm high. Both broadcast barley treatments were killed off with 0.5 kg a.i./ha (1983) or 0.25 kg a.i./ha fluazifop-p-butyl plus 250 ml/ha non-ionic wetter ('Agral') in 210 l/ha of water with a tractor mounted hydraulic sprayer at a pressure of 300 kPa through Spraying Systems 11003 'TeeJet' nozzles.

TABLE 2

Diary for sugar beet experiment

	1983		1984	
	Date	Days before/ after beet drilled	Date	Days before/ after beet drilled
Early barley drilled	28 February	-33	21 February	-29
Late barley drilled	21 March	-12	20 March	- 1
Straw planted	7 April	+ 5	28 March	+ 7
Sugar beet drilled	2 April	0	21 March	0
Barley sprayed with fluazifop	27 May	+55	17 May	+57

In both series of trials broad-leaved weeds were controlled by repeat low dose herbicide programmes equally across all treatments.

Because of plot size and the shelter policy used in adjoining crop areas no serious wind damage occurred in either of these trial series and differences in yield where they occur can be attributed to the different treatments applied.

RESULTS

Onions

The effect of shelter treatments on plant population at harvest, bulb yield and size distribution within the marketable fraction has been measured.

TABLE 3

Onion plant population at harvest

Crop shelter system	Population (plants/m^2)		
	1982	1983	1984
SED	(±1.6)	(±8.5)	(±3.0)
No shelter	63	55	60
Inter-row planted straw	61	54	61
Inter-row cereals - early kill	66	51	60
Inter-row cereals - late kill	63	46	53
Inter-row transplanted onions			
- Drilled crop	64	(62*)	65
- Transplanted crop	19		28

*Total number only recorded.

Treatments had no significant effect on plant population of the drilled crop although there was a trend in 1983 and 1984 for the late killed inter-row barley to reduce the survival of the drilled crop.

TABLE 4

Marketable yield of onions

Crop shelter system	Yield over 40 mm diameter (t/ha)			
	1982	1983	1984	Mean
(SED)	(±2.27)	(±2.87)	(±4.63)	
No shelter	27.4	39.2	49.3	38.6
Inter-row planted straw	27.1	37.6	54.9	39.8
Inter-row cereals - early kill	28.6	35.6	53.6	39.2
Inter-row cereals - late kill	23.9	32.5	35.5	30.6
Inter-row transplanted onions (yield of drilled and transplanted crop)	26.3	47.4	63.4	45.7

The late kill of the inter-row barley resulted in a significant yield depression in two of the three years when compared to either no shelter or straw planting. The use of transplanted module grown onions to provide shelter for the drilled crop gave an expected yield increase, except in 1982 when, in the absence of irrigation, the increased population produced many bulbs below the 40 mm minimum for ware onions.

TABLE 5

Size distribution of marketable ware onions

Crop shelter system	Distribution of onions in 40-60 mm and 60-80 mm grades as percentage of total marketable yield over 40 mm					
	1982		1983		1984	
	40-60 mm	60-80 mm	40-60 mm	60-80 mm	40-60 mm	60-80 mm
No shelter	90	8	68	24	45	51
Inter-row planted straw	91	8	68	24	46	51
Inter-row cereals - early kill	92	7	65	26	42	52
Inter-row cereals - late kill	94	5	65	26	45	46
Inter-row transplanted onions (both drilled and transplants)	92	8	59	27	65	24

Seasonal effects had a large influence on size distribution particularly in 1982 when irrigation was not applied. Only with the inter-row transplanted modules in 1984, where total populations were very much higher, did a shelter treatment markedly affect size distribution.

Sugar Beet

The effect of shelter treatment on plant population, root yield, percent sugar content and sugar yield was measured.

TABLE 6

Population and yield of sugar beet

Crop shelter system	Plant population at harvest (thous/ha)		Sugar yield (t/ha)	
	1983	1984	1983	1984
(SED)	(±4.61)	(±3.50)	(±1.46)	(±0.45)
No shelter	65.2	77.6	11.2	10.6
Early sown broadcast barley	70.4	77.0	10.3	10.8
Late sown broadcast barley	67.6	75.0	10.7	10.6
Inter-row planted straw	63.2	73.0	11.6	10.7

In 1983 the barley cover crop was killed off on 27 May, 55 days after the sugar beet was drilled. As assessment was made of top growth on 13 June by measuring the weight of green leaves. When expressed in percentage terms these were 100.0, 74.6, 74.3 and 101.5 for the no shelter, early broadcast barley, late broadcast barley and inter-row planted straw treatments respectively. Harvested yields indicated that those effects on leaf weight were carried through and influenced the final sugar yield. In 1984 the barley cover crop was killed off on 17 May, 57 days after the sugar beet was drilled, and there was no difference in yield between the shelter treatments.

DISCUSSION

Onions

Although the use of transplanted module raised onions appears attractive there are considerable husbandry problems including the relatively high cost of the system, the impact of the increased population on size distribution of the bulbs, higher irrigation requirement and particularly the differential maturity at harvest. Inter-row straw has worked well over the years and hardly any cases of wind damage have been reported where this technique has been used. The technique involves specialist machinery and additional labour. Costs have been calculated at around £76/ha. Inter-row barley is a cheaper technique and although costs have been calculated at only around £31/ha, this technique does not provide immediate shelter. Experience indicates that even at a seed rate of 40 kg/ha (to achieve a population of 110 plants/m run of the inter-row cereal) it is often late April before the barley reaches the three true leaf stage of growth necessary for effective protection. Delayed kill of the inter-row barley causes crop competition and has resulted in yield loss. As can be seen in these trials, a delay of only 11 days in 1982 produced a yield depression of 4.7 t/ha, 6 days in 1983 of 3.1 t/ha, and 14 days in 1984 of 18.1 t/ha. With the more prolonged risk of wind damage in onions and the relatively narrow window for controlling a live cover crop before competition occurs, inter-row straw planting has practical advantages for this crop. The yield reduction in onions from delayed killing of the cereal cover crop could have been due either to the onions being at a stage of growth where they are particularly sensitive to competition or to the increased competitive effect of the rapidly growing cover crop. This could imply that a grass-weed population at this stage of growth could similarly affect crop yields.

Sugar Beet

Although competition between the live cover crop and the sugar beet has occurred, this has not been severe, and in good growing conditions in the later part of the season the crop may be able to compensate. More recent work by the Arthur Rickwood EHF, by British Sugar PLC, and ICI PLC suggests that the use of inter-row instead of broadcast barley cover crops, combined with a sensible killing off date could reduce the risk of competition. In 1985 populations of 55 or 110 plants/m run of the inter-row cereal were established from seed rates equivalent to 20 and 40 kg/ha and the lower population seemed adequate during the spring to reduce the risk of a blow. With the broadcast system only the higher seed rate seemed adequate. The lower cost structure and ease of establishment of a live cover crop combined with the lower risk of wind damage to the sugar-beet crop encourages many sugar-beet growers to prefer this system of sheltering their crops.

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TOLERANCE OF SEED POTATO CROPS TO A RANGE OF SELECTIVE GRAMINICIDES

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ABSTRACT

Four selective graminicides were applied to weed-free plots of potato cv Maris Piper in early July to evaluate effects on crops grown for seed production. Alloxydim-sodium, fluazifop-butyl and sethoxydim were compared against one another in two experiments; quizalofop-ethyl was tested by itself in a third experiment. Rates of application were those recommended for the control of perennial grass weeds, and three times those rates. None of the herbicide treatments adversely affected yield or quality of tubers, or their subsequent growth when chitted. Both rates of alloxydim-sodium reduced haulm weights slightly in one experiment, without producing any visible leaf malformation. However, quizalofop-ethyl caused yellow blotching of treated foliage, more severe at the treble rate, which persisted until haulm removal. This effect was unacceptable in a crop grown for seed certification, since it resembled or might have masked viral infection. The other three herbicides appeared to have adequate safety margins for selective use in seed potato crops.

INTRODUCTION

The number of selective graminicides being evaluated for control of grass weeds post-emergence of potato crops has increased steadily over recent years. Most of the published information relates to ware crops and concentrates on comparative weed control performance rather than crop tolerance e.g. Schumacher et al. (1982). Field evidence on safety to the crop tends to be confounded with the beneficial effects of weed removal or suppression and to refer only to gross yield, e.g. Gibbard et al. (1982). Seed crops are particularly vulnerable to injury by herbicides because of their short growing season, their inspection for certification and the risk of effects on the subsequent growth of daughter tubers. Selective graminicides are likely to be applied mainly for the control of perennial grasses during the later stages of canopy development of the potato crop, i.e. much later than is normal for most potato herbicides. The above factors therefore merit particular attention before these herbicides can be recommended with confidence for use in crops grown for seed.

MATERIALS AND METHODS

Three experiments were carried out at Invergowrie on crops of cv Maris Piper grown for seed production. Plots consisted of two rows each of 27 plants, plus shared guard rows. Tubers (45-55 mm diameter) were planted at 30 cm spacing in rows 70 cm apart, giving a plot size of 8.1 m by 2.1 m. Treatments were arranged in randomised blocks and replicated three times. Two sets of untreated plots were included in each replicate. Rates of application of the graminicides were those initially recommended for the control of perennial grass weeds and three times that dosage, as shown below:

Herbicide	Dose kg a.i./ha	
	Single	Treble
Alloxydim-sodium	1.50	4.50
Fluazifop-butyl*	0.75	2.25
Sethoxydim	0.87	2.61
Quizalofop-ethyl**	0.38	1.13

* plus non-ionic wetting agent 'Agral' at 0.1% by volume

** plus adjuvant oil 'Fyzol' 11E at 2 l/ha

The first three herbicides were evaluated against one another in two identical experiments in 1982 (Experiment I) and 1983 (Experiment II). Quizalofop-ethyl was included in a preliminary evaluation with a range of other post-emergence herbicides (none of them graminicides) in 1984 (Experiment III).

In all three experiments the graminicides were applied by Oxford Precision Sprayer in a water volume of 500 l/ha, using 'Teejet' (50-04) nozzles at 240 kPa, when the crop foliage reached 50-70% canopy cover, i.e. just before passage through the crop would have caused mechanical injury to the haulm.

Routine applications of insecticides and fungicides were made to the field crops as and when necessary for protection against aphids and potato blight. The crops were not irrigated. Weeds were controlled by an application of terbutryne + terbuthylazine (1.0+0.4 kg a.i./ha) plus a contact herbicide well before crop emergence, supplemented by hand-weeding.

Potato haulm was cut and removed by hand, when the majority of tubers were of seed size (35-55 mm diameter). Tubers were harvested and graded and samples were assessed for internal vascular browning, disease incidence, skin set, specific gravity and sugar content. Seed-size tubers were stored in trays until mid February in the dark at 2°C and then submitted to a chitting regime of 12 h light and 12 h dark, both at 15°C, until late April. Records were taken of sprout numbers and growth on ten tubers per plot. Dates of relevant operations were as follows:

	Expt I	Expt II	Expt III
	1982-83	1983-84	1984-85
Tubers planted	20 April	25 April	16 April
Graminicides applied	8 July	6 July	2 July
Haulm cut	9 August	29 August	30 August
Tubers harvested	15 September	21 September	16 October
Chitting started	15 February	14 February	8 February

RESULTS

In all three experiments, the herbicides were applied to actively-growing foliage in fine sunny weather, with no rain for at least 24 h

TABLE 1

Expts I-III Harvest records

Herbicide	Dose	F.wt/ haulm t/ha	F.wt tubers t/ha		Tuber nos./plot		% d.m. tubers
			Total	Seed‡	Total	Seed‡	
Expt I							
Untreated		25.5	38.5	27.0	664	447	23.0
S.E. mean ±		1.15	1.67	1.47	22.2	23.6	0.28
Alloxydim	1	24.4	41.8	29.5	729	479	23.3
	3	23.3	38.8	29.8	717	489	23.8
Fluazifop	1	23.1	41.8	31.4	697	502	23.4
	3	27.4	40.2	27.0	678	437	22.7
Sethoxydim	1	25.3	41.3	28.6	668	449	23.3
	3	23.8	43.7	32.1	707	493	24.1*
S.E. mean ±		1.62	2.36	2.08	31.4	33.4	0.39
Expt II							
Untreated		16.4	35.3	27.6	1070	567	25.2
S.E. mean ±		0.59	0.96	0.87	31.5	15.2	0.29
Alloxydim	1	13.9*	33.8	26.7	1025	543	25.3
	3	13.6*	32.3	25.2	1058	539	25.1
Fluazifop	1	14.4	32.0	24.9	1050	527	25.9
	3	15.7	34.7	27.3	1080	563	24.7
Sethoxydim	1	15.1	33.8	26.9	1057	540	25.1
	3	15.4	35.9	29.0	1075	576	25.0
S.E. mean ±		0.83	1.36	1.23	44.6	21.5	0.41
Expt III							
Untreated		19.9	42.6	35.5	865	607	23.7
S.E. mean ±		1.10	2.10	1.71	25.0	21.6	0.29
Quizalofop	1	20.5	44.3	35.8	939	619	23.3
	3	20.0	43.5	34.5	906	601	23.1
S.E. mean ±		1.55	2.97	2.42	35.3	30.5	0.41

* Significantly different from Untreated at the 5% level.

‡ 35-55 mm diameter.

thereafter. Haulm removal took place before the onset of natural senescence, so no assessment of possible effects on rate of senescence was possible. None of the herbicide treatments in Expts I and II caused any leaf malformation or visible growth check to haulm, but both rates of alloxydim-sodium slightly reduced haulm fresh weights in the latter experiment (Table 1). In Expt III, by contrast, application of quizalofop-ethyl resulted within a few days in irregular-sized yellow

TABLE 2

Expts I-III Chitting records per ten tubers

Herbicide	Dose	Expt I 1983		Expt II 1984		Expt III 1985	
		A 14 March	B 21 April	A 15 March	B 20 April	A 6 March	B 30 April
Untreated		14.7	18.8	13.2	20.1	12.5	25.1
S.E. mean ±		0.66	1.27	0.61	0.95	0.29	1.85
Alloxydim	1	13.5	18.0	14.6	20.9	-	-
	3	16.7	18.5	13.5	19.9	-	-
Fluazifop	1	14.2	18.0	14.7	24.0*	-	-
	3	16.0	18.6	15.0	23.3	-	-
Sethoxydim	1	16.2	17.4	13.8	20.7	-	-
	3	14.2	16.1	15.1	18.6	-	-
Quizalofop	1	-	-	-	-	13.0	24.9
	3	-	-	-	-	13.1	28.5
S.E. mean ±		0.94	1.79	0.86	1.35	0.42	2.61

* Significantly different from Untreated at the 5% level.
A Mean length (mm) of longest sprout/tuber.
B Fresh wt all sprouts (g).

patches appearing on treated potato foliage; the symptoms were particularly severe at the treble rate and at leaf bases. These symptoms were not accompanied by leaf malformation, stunting or necrosis, but persisted unaltered until haulm removal. There was no reduction in fresh weight of haulm in comparison with untreated plots.

In none of the three experiments did individual herbicide treatments have any adverse effect on numbers, weights, size distribution or percentage dry matter of harvested tubers (Table 1). Nor were there any significant overall factorial effects of either herbicide or dose in Expts I and II. Assessment of tubers in relation to internal vascular browning, skin set, disease incidence, sugar content and colour showed no evidence of differences between untreated and herbicide-treated plots in any year.

Chitting records showed no harmful effects of herbicide treatment on sprout production or rate of development in any of the three experiments (Table 2). Fluazifop-butyl may possibly have enhanced growth slightly in Expt II. Sprouts on all tubers were of normal colour and shape.

Chitted and unchitted tubers from plots originally treated with quizalofop-ethyl were planted in the field in 1985 to check whether or not the yellow leaf patches reappeared in the daughter crop's foliage. They did not, and haulm growth was in no way different from that of tubers from comparable untreated plots.

DISCUSSION

Ideally, infestations of perennial grasses in fields to be planted with seed potatoes should be dealt with in the previous autumn, e.g. by use of glyphosate before or after cereal harvest. A substantial proportion of the crop is however grown on rented land where the grower has no control over rotational weed-control practices. Until recently, growers on rented land had the useful option of applying EPTC during soil preparation prior to planting if the field was found to have an infestation of species such as *Elymus repens* (L.) Gould. (Jones & Orson 1982). The development of stone separation techniques to permit easier harvesting of seed potato crops has however made incorporation of EPTC impracticable in fields where stones are placed in regular 'windrows' across the field. Stone separation rapidly became standard practice for seed potato producers in Scotland during the early 1980s, thereby creating a demand for alternative methods of controlling perennial grass weeds. Fortunately the first group of selective graminicides came into development at that time and several of them are capable of effective post-emergence suppression of species such as *E. repens* in potatoes (Davies & Richards 1984, Gibbard *et al*. 1982, Jones & Orson 1982, Schumacher *et al*. 1982). This type of treatment particularly suits the stone-separated seed potato crop, provided there are no adverse effects on haulm growth in relation to inspection for certification, or on any aspect of current or subsequent growth of the daughter tubers.

Our results showed no harmful effects on tuber yields or quality or on subsequent chitting behaviour with any of the four herbicides tested, even at three times the rate initially recommended for control of perennial grasses. In an associated series of trials in Eastern Scotland, Davies and Richards (1984) recorded a significant yield reduction in ware crops at one out of six sites treated with sethoxydim or fenthiaprop-ethyl, but no such effects with alloxydim-sodium or fluazifop-butyl. In 1983 all four herbicides caused varying levels of foliar scorch shortly after application and slightly retarded foliage development, but the relative ranking of individual treatments was not consistent between sites for either effect.

Neither minor foliar scorch nor a slight check to foliage development need necessarily present any problems to a potato certification inspector. The foliar effects produced by quizalofop-ethyl in our 1984 experiment were of a quite different character and importance and have not so far been reported with any of the other graminicides. However, in a demonstration trial in which a wide range of commercial potato cultivars was treated with quizalofop-ethyl in 1985 (D. Hall, DAFS Agricultural Scientific Services - personal communication), this herbicide produced exactly the same foliar effects, across all cultivars, as those which occurred in cv Maris Piper in our 1984 experiment. The phenomenon does not therefore appear to be related to individual cultivars or growing seasons. These foliar symptoms effectively preclude the use of this graminicide in seed potato crops, since they closely resemble and could be confused with or mask virus infection and are likely to be present during the main period of potato inspection for certification. Any other new members of the selective graminicide group being considered for use in potatoes should be checked for this type of effect.

Our experimental treatments were applied as late in the growing season as would be practicable in seed crops and included three times the dose initially recommended for control of perennial grasses. The recommended rate of alloxydim-sodium has since been raised to 1.88 kg a.i./ha. Nevertheless our results suggest that alloxydim-sodium, fluazifop-butyl and sethoxydim should normally have ample margins of safety in relation to the yield, quality and subsequent performance of seed tubers. Further information is, however, desirable on the environmental factors which occasionally result in foliar scorch and/or a check to foliage growth with all three herbicides and on any possible interactions which may result from changes in formulation or the addition of wetters or adjuvants. Alloxydim-sodium is currently the only member of the selective graminicide group officially Approved for use in ware and seed potato crops in the United Kingdom and is applied without either wetter or adjuvant. Results to date indicate that it can safely be included in weed control strategies for modern systems of seed potato production. The other herbicides still await full commercial Clearance for use in any type of potato crop in the United Kingdom.

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FACTORS AFFECTING CONTROL OF *ELYMUS REPENS* IN SOYBEANS WITH SELECTIVE POST-EMERGENCE HERBICIDES

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ABSTRACT

The effects of adjuvants, single or sequential applications, cultivation following application, tank mixing with broad-leaved herbicides, crop row spacing, and spray volume on control of *Elymus repens* in soybeans with selective post-emergence herbicides were evaluated in field trials conducted from 1977 to 1985. Excellent control was obtained when fluazifop-butyl, haloxyfop-methyl, and DPXY 6202 (2-(4-((6-chloro-2-quinoxalinyl)oxy)-phenoxy)propionic acid) were applied to *E. repens* in the three to six-leaf stage. Sethoxydim gave less effective control. Adjuvants enhanced the performance of all compounds, single applications were as effective as sequential treatments and cultivation after treatment seldom improved control. Simultaneous application of grass herbicides with bentazon was antagonistic for haloxyfop-methyl, fluazifop-butyl and sethoxydim but not with DPXY 6202. Performance at all grass herbicides was reduced when applied simultaneously with acifluorfen. Row spacing did not affect herbicide performance and water volumes of 20 to 300 l/ha gave equivalent control. All herbicides significantly reduced *E. repens* growth the year after application.

INTRODUCTION

Elymus repens is the most abundant perennial grass affecting crop production in the north central region of the USA (Doll 1983). Until the introduction of glyphosate, growers were discouraged from planting soybeans in fields infested with *E. repens*. Preplough treatments with glyphosate gave the first opportunity to control this weed the same season soybeans were planted. More recently, the advent of selective post-emergence graminicides allowed growers to consider planting soybeans into fields with *E. repens* and treat as needed after crop and weed emergence. The purpose of this research was to evaluate the factors that affect the performance of selective post-emergence grass herbicides on *E. repens*. These factors included herbicide rate, spray volumes, adjuvants, single or sequential applications, cultivation following treatment, row spacing, and interactions with post-emergence broad-leaved herbicides. The effects of treatments the year after application were monitored in several trials and the losses due to uncontrolled *E. repens* in soybeans were determined for all trials.

MATERIALS AND METHODS

Trials were conducted from 1977 to 1985 at the Arlington Experiment Station of the University of Wisconsin (43^o20'N 89^o23'W) on a Plano silt loam (fine-silty mixed, mesic, Typic Argiudoll) with 3.2 to 3.6% organic matter and a pH of 6.4 to 6.8. Sites were typically old alfalfa fields heavily infested with *E. repens* which were spring ploughed, disced, and field cultivated before planting 400,000 soybean seeds/ha between 9 May and 25 May. Appropriate pre-emergence herbicides were applied to control annual broad-leaved and grass weeds without affecting *E. repens*. Trial design was a randomized complete block with three or four replications. Plots were 3 m wide and 7 or 8 m long with conventional row widths of 75 cm. *E. repens* control in narrow row spacing of 18 cm was examined in two trials.

Most treatments were made to *E. repens* in the three to four-leaf stage approximately 30 days after planting. Herbicides evaluated included sethoxydim, fluazifop-butyl (contained equal proportions of the R and S isomers), fluazifop-P-butyl (contained only the R isomer), haloxyfop-methyl, and DPXY 6202 (2-(4-((6-chloro-2-quinoxalinyl)oxy)-phenoxy)propionic acid). Unless otherwise stated all treatments were applied in 200 l/ha with a CO_2 powered hand-held sprayer operated at 1260 to 1550 mm Hg pressure and fitted with appropriate flat fan nozzles. In 1981 and 1984 experiments compared spray volumes of 20, 50, 100, 200 or 300 l/ha. The 20 l/ha volume was applied with a hand-held battery-powered rotary disc nozzle which covered a 1.2 m swath. The higher volumes used appropriate flat fan nozzles fitted to the hand-held sprayer. Unless otherwise stated, all applications were made with 1% (v/v) crop oil concentrate (an emulsifiable nonphytotoxic petroleum-based oil with no less than 15% surfactant). When split applications of the graminicides were evaluated, the second treatment was made 14 days after the first one. If interrow cultivation followed the herbicide treatment, it was done 14 days after application. Visual control ratings were taken several times during each season and soybean yield was measured at crop maturity by mechanically harvesting the centre rows of each plot. *E. repens* reinfestation the year after treatment was evaluated in several trials after soybeans or alfalfa had been planted the following season.

RESULTS AND DISCUSSION

Herbicides

Most of the compounds tested effectively controlled *E. repens*. The order of effectiveness (based on equal rates of active ingredient) is as follows: DPXY 6202   haloxyfop-methyl = fluazifop-butyl   fluazifop-P-butyl sethoxydim. With the exception of sethoxydim, greater than 90% control was obtained from all herbicides at rates similar to those recommended for annual grass control. Thus equivalent control can be obtained from most compounds. Applications made to *E. repens* in the two to four or four to six-leaf stage gave satisfactory control. In drier years, delaying the application until the later growth stage resulted in better control because more *E. repens* had emerged by treatment time (data not presented).

Spray Volume

Spray volumes had relatively little effect on the performance of the two herbicides tested, fluazifop-butyl or sethoxydim, for control of *E. repens*. The control obtained from 20 l/ha applied with the spinning disc nozzle was generally similar to that from higher volumes applied with flat fan nozzles. In situations where crop foliage or other weeds would intercept some of the spray droplets, higher volumes might be more effective. The effect of spray volume on the performance of these materials may vary with plant species. For example, Buhler and Burnside (1984) reported enhanced activity of fluazifop-butyl, haloxyfop-methyl and sethoxydim on forage sorghum as spray volume decreased.

Additives

All compounds performed best when applied with a surfactant or crop oil concentrate (Table 1). Similar results were obtained by Ivany (1984). Oil concentrates were slightly more effective than surfactants.

TABLE 1

Effect of additives on *E. repens* control with sethoxydim, fluazifop-butyl and haloxyfop-methyl.

Year	Treatment	Rate (kg a.i./ha)	Adjunant[1]	*E. repens* control (%) early	late[2]	Soybean yield (kg/ha)[3]
1978	sethoxydim	1	--	64	80	1522
1978	sethoxydim	1	surf	83	94	1574
1978	check	--	--	0	0	1119
1981	fl-butyl	1	surf	79	89	2832
1981	fl-butyl	1	oil concn	82	97	3164
1981	haloxyfop	.5	surf	94	97	3457
1981	haloxyfop	.5	oil concn	93	98	3476
1981	check	--	--	0	0	3206
1982	fl-butyl	.25	--	41	25	2145
1982	fl-butyl	.25	surf	52	52	2036
1982	fl-butyl	.25	oil concn	61	76	2963
1982	check	--	--	0	0	1226
1983	fl-butyl	.25	surf	83	93	--
1983	fl-butyl	.25	oil concn	84	92	3827
1983	check	--	--	0	0	2932

[1] surf = surfactant X-77 at .25%, v/v; oil concn = crop oil concentrate at 1%, v/v.

[2] Early and late ratings taken at 15 and 60 to 90 days after application, respectively.

[3] LSD (.05) = 278, 463, 495, and 418 kg for 1978, 1981, 1982 and 1983, respectively

Split applications

Split applications are expected to be advantageous over single treatments because perennial weeds often emerge over an extended period. However, when the same quantity of herbicide was applied in either one or two applications, the degree of control was usually similar and in a few years actually favored by single treatments (Table 2). Hicks and Jordan (1984) found split applications of sethoxydim to *E. repens* advantageous under glasshouse conditions with no crop competition. Davidson *et al.* (1985) also observed improved performance with sequential treatments with sethoxydim and fluazifop-butyl on this weed in fields of birdsfoot trefoil. Soybean competition after the initial application is apprently sufficient to maintain full season control of *E. repens*. Also, no differences in *E. repens* population the year after treatment were observed between single and sequential applications.

Inter-row cultivation

When a single application of these compounds was followed by an inter-row cultivation 14 days later, control from sethoxydim was improved nearly 25%, but little enhancement from cultivation was noted with fluazifop-butyl, haloxyfop-methyl or DPXY 6202 except when dry weather in 1984 resulted in less than optimum herbicidal action (data not presented). Another frequent advantage of cultivation after treatment was the control of broad-leaved weeds that had escaped the pre-emergence herbicide.

Row spacing

In 1983 and 1984, sethoxydim gave better *E. repens* control in narrow-row than wide-row soybeans, especially at the lower rate (Table 3). A similar response occurred with fluzaifop-butyl in 1984 but not for the other herbicides. It appears that soybeans in narrow rows gave better *E. repens* suppression in narrow rows which sometimes improved overall control.

Interaction with Broad-Leaved herbicides

Post-emergence broad-leaved products such as bentazon and acifluorfen are known to be antagonistic with selective graminicides such that the control of other grass species is reduced (Banks & Tripp 1983, Rhodes, Jr. & Coble 1984). The results in Table 4 show that acifluorfen and bentazon are very antagonistic with haloxyfop-methyl and slightly antagonistic with fluazifop-butyl, fluazifop-P-butyl and sethoxydim. Acifluorfen also reduced the performance of DPXY 6202 on *E. repens* but bentazon was not antagonistic with this product. A three-day interval between applications reduced but did not eliminate the antagonism. Excellent *E. repens* control can be maintained in tank-mix applications by increasing the rate of the grass herbicide. Tank-mixes of fluazifop-butyl, fluazifop-P-butyl, haloxyfop-methyl and DPXY 6202 with acifluorfen also increased crop injury as compared to sequential applications. Thus broad-leaved weed control herbicides should not be applied simultaneously with selective graminicides.

Long term control

The effects of a single application of these compounds persisted for more than one season. After the 1980 and 1982 applications, *E. repens* population was only 25% of that in the untreated plots. Regrowth following the 1984 application was dramatically reduced to less than 5% in 1985 by all compounds (data not presented). The nearly ideal conditions at the time of treatment in 1984 and the much drier than normal weather in early 1985 probably account for the great regrowth reduction observed that year.

Yields

Yield losses due to weeds vary considerably from year to year. Uncontrolled *E. repens* reduced soybean production from 4 to 70% over the eight-year period. The lower yield reductions in 1977 and 1981 are attributed to dry weather early in the season which affected *E. repens* more than soybeans. The overall average yield loss on untreated plots of 40% verifies that uncontrolled *E. repens* seriously affects crop production and the benefits of treatment are economically justified, particularly since the effects are evident for more than one season. Yield data in Tables 1 to 4 indicate that no significant losses occur unless *E. repens* control is less than 80%.

TABLE 2

Effect of single and split applications of sethoxydim, fluazifop-butyl and haloxyfop-methyl on *E. repens* control.

Year	Treatment[1]	Rate (kg a.i./ha) a.i.	*E. repens* control (%)[2]		Soybean yield (kg/ha)[3]
			early	late	
1979	sethoxydim	1.0	63	90	2584
1979	sethoxydim	.5/.5	93	94	3332
1979	check	--	0	0	1324
1980	sethoxydim	.75	74	82	2406
1980	sethoxydim	1.0	72	90	2362
1980	sethoxydim	.5/.25	78	82	2209
1980	sethoxydim	.5/.5	80	88	2515
1980	check	--	0	0	544
1981	sethoxydim	.5	76	87	3535
1981	sethoxydim	.25/.25	81	88	3281
1981	fl-butyl	.5	79	89	2832
1981	fl-butyl	.25/.25	77	97	3281
1981	check	--	0	0	3206
1983	fl-butyl	.25	84	92	3827
1983	fl-butyl	.375	83	95	--
1983	fl-butyl	.50	86	94	3080
1983	fl-butyl	.125/.125	78	83	3362
1983	fl-butyl	.25/.125	84	97	--
1983	fl-butyl	.25/.25	87	93	3190
1983	haloxyfop	.188	90	97	--
1983	haloxyfop	.25	93	97	3376
1983	haloxyfop	.125/.063	90	94	--
1983	haloxyfop	.125/.125	90	93	2740
1983	check	--	0	0	2566
1985	haloxyfop	.125	80	91	--
1985	haloxyfop	.188	81	84	--
1985	haloxyfop	.062/.062	23	56	--
1985	haloxyfop	.125/.062	79	91	--
1985	check	--	0	0	--

[1] All treatments applied with 1%, v/v, crop oil concentrate.

[2] Early and late ratings taken 15 and 60 to 90 days after application, respectively.

[3] LSD (.05) = 527, 551, 463 and 771 kg for 1979, 1980, 1981 and 1983, respectively.

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TABLE 3

Effect of soybean row spacing on *E. repens* control with several post-emergence herbicides.

Year	Treatment[1]	Rate (kg a.i./ha)	Row spacing (cm)	*E. repens* control (%)		Soybean yield (kg/ha)[3]
				early	late[2]	
1983	sethoxydim	.50	18	86	96	--
1983	fl-butyl	.25	18	78	94	3628
1983	fl-butyl	.375	18	86	89	--
1983	haloxyfop	.125	18	87	92	4386
1983	haloxyfop	.250	18	86	96	--
1983	check	--	18	0	0	3323
1983	sethoxydim	.50	75	88	72	2829
1983	fl-butyl	.25	75	84	92	3827
1983	fl-butyl	.375	75	83	95	--
1983	haloxyfop	.125	75	89	89	3096
1983	haloxyfop	.250	75	90	97	--
1983	check	--	75	0	0	2566
1984	sethoxydim	.25	18	69	54	2488
1984	sethoxydim	.50	18	84	82	2769
1984	fl-butyl	.125	18	93	94	2599
1984	fl-butyl	.188	18	94	93	2464
1984	haloxyfop	.125	18	90	87	2086
1984	DPXY 6202	.125	18	92	92	2289
1984	DPXY 6202	.188	18	91	89	2231
1984	check	--	18	0	0	1065
1984	sethoxydim	.25	75	47	52	2309
1984	sethoxydim	.50	75	77	81	2238
1984	fl-butyl	.125	75	79	79	2417
1984	fl-butyl	.188	75	85	88	2494
1984	haloxyfop	.125	75	94	94	2492
1984	DPXY 6202	.125	75	88	95	2461
1984	DPXY 6202	.188	75	94	99	2447
1984	check	--	75	0	0	1498

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[1] All treatments applied with 1%, v/v, crop oil concentrate.

[2] Early and late ratings taken at 15 and 60 to 90 days after application, respectively.

[3] LSD (.05) = 418 kg in 1983 and 878 kg in 1984.

TABLE 4

Interaction of bentazon and acifluorfen with several post-emergence graminicides on *E. repens* control.

Year	Treatment[1]	Rate (kg a.i./ha)	*E. repens* control (%) early	late[2]	Soybean injury (%)	yield (kg/ha)[3]
1983	fl-butyl	.25	78	94	0	3628
1983	fl-butyl+bentazon	.25+1	81	96	6	--
1983	fl-butyl/bentazon[4]	.25/1	85	97	12	--
1983	fl-butyl+acifluorfen	.25+.5	82	92	23	--
1983	fl-butyl+acifluorofen[4]	.25/.5	78	89	11	--
1983	check	--	0	0	0	3323
1984	fl-butyl	.125	85	97	0	3835
1984	fl-butyl+bentazon	.125+1	84	91	0	4003
1984	bentazon/fl-butyl[5]	1/.125	90	93	0	3778
1984	fl-butyl	.188	90	97	0	3861
1984	fl-butyl+bentazon	.188+1	92	97	3	3784
1984	bentazon/fl-butyl[5]	1/.188	93	96	0	3843
1984	fl-butyl+acifluorfen	.188+.5	90	85	19	3485
1984	acifluorfen/fl-butyl[5]	.5/.125	90	89	12	3685
1984	acifluorfen/fl-butyl[5]	.5/.188	91	95	7	3745
1984	haloxyfop	.125	94	97	0	3728
1984	haloxyfop+bentazon	.125+1	82	74	0	3522
1984	bentazon/haloxyfop[5]	1/.125	96	96	0	3811
1984	haloxyfop+acifluorfen	.125+.5	88	84	25	3376
1984	DPXY 6202	.125	95	98	0	3931
1984	DPXY 6202+bentazon	.125+1	96	97	0	3636
1984	bentazon/DPXY 6202[5]	1/.125	97	97	0	3822
1984	DPXY 6202+acifluorfen	.125+.5	91	87	21	3538
1984	acifluorfen/DPXY 6202[5]	.5/.125	97	96	12	3688
1984	check	--	0	0	0	1702

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[1] All treatment applied with 1%, v/v, crop oil concentrate except acifluorfen which was applied with .25%, v/v, X-77 surfactant.

[2] Early and late ratings taken at 15 and 60 to 90 days after planting, respectively.

[3] LSD (.05) = 418 kg in 1983 and 331 kg in 1984.

[4] Grass herbicide applied one day earlier.

[5] Broad-leaved herbicide applied three days earlier.

Soybean producers may choose from various *E. repens* control strategies. Until the introduction of selective post-emergence graminicides, preplough application of glyphosate was the only alternative available to control this weed in the year of planting. Now post-emergence applications of highly selective herbicides can be applied to infested fields as necessary. These compounds have no soil residue carryover to affect subsequent crops which allows total flexibility in planning crop rotations. Also subsequent crops will have less *E. repens* because the effects of the selective graminicides are evident for more than one year. In order to obtain effective *E. repens* control from these compounds, they should be applied (1) when the weed has three to six leaves and is actively growing, (2) with a crop oil concentrate, (3) as a single treatment, (4) by themselves and not in combination with broad-leaved herbicides and (5) in water volumes between 50 to 300 l/ha. The control strategy is generally the same regardless of row spacing and a follow-up cultivation is necessary only to control escaping broad-leaved weeds.

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COMPARATIVE EFFICACY OF SEVERAL GRAMINICIDES IN CONTROLLING ELYMUS REPENS

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ABSTRACT

Several field and controlled environment experiments were conducted between 1981 and 1984 to evaluate the efficacy of a number of herbicides: sethoxydim, haloxyfop-methyl and glyphosate for the control of *Elymus repens*. Periodic excavation and collection of *E. repens* shoots over a three year period showed that all three compounds provided weed control for more than one season from a single application. Shoot regrowth was most evident in the sethoxydim treatment relative to the others. All herbicides provided long-term rhizome control in excess of shoot control. Controlled environment studies evaluating rhizome bud viability changes with herbicide treatment showed all plants had increasing bud viability with increasing distance from the primary shoot. Under these more favourable conditions sethoxydim and haloxyfop-methyl provided better control of rhizome buds than glyphosate. Controlled environment studies with the ^{14}C-labelled analogues of these compounds revealed that ^{14}C-sucrose and haloxyfop-methyl had a fairly even distribution between the buds of new rhizome growth. Sethoxydim preferentially accumulated in the apical rhizome tips. Glyphosate rhizome distribution was intermediate to this. As temperature increased, greater amounts of all three compounds translocated to untreated shoot portions of the plant relative to the rhizome system. This shift occurred at lower temperatures with sethoxydim than the other compounds. The tendency of sethoxydim to accumulate in rhizome tips, and its tendency to move to shoots rather than rhizomes at field temperatures, could explain the early regrowth observed with this chemical subsequent to treatment in the field

INTRODUCTION

Elymus repens is a major weed problem in Ontario, especially in mixed farming (such as dairy and swine) operations that rely on crop rotations extensively. The recent introduction of several graminicides has provided new crop management options to these growers. From 1981 to 1984 several studies were conducted to ascertain how effectively they control *E. repens*, and how they fit into existing crop production systems. This paper represents an overview of some of the central experiments designed to evaluate the efficacy of several herbicides, and to discern factors that influence their behavior in *E. repens*. The objectives of those studies were 1) to determine the long term effects of a single application of three herbicides on *E. repens* shoots and rhizomes in the field; 2) to compare the movement of three chemicals as measured by their effect on rhizome bud viability; 3) to determine the distribution of ^{14}C-labelled compounds within the rhizome system; and 4) to determine the effect of temperature on the distribution of three compounds within the rhizome system.

MATERIALS AND METHODS

Studies were conducted at the field research facilities at the Elora Research Station, Wellington Co., Ontario, Canada, and in controlled environment facilities within the Crop Science Building, University of Guelph. Field experiments were on a field heavily infested with E. repens sod. Rhizome material from this field was utilized in the controlled experimentation. All experiments included several other treatments but the treatments presented here represent the range of efficacy observed within the larger group of chemicals.

Experiment 1

A study evaluated the long term effects of several herbicides on E. repens growth in the field. In the spring of 1981 the entire area was mouldboard ploughed to a depth of 20 cm and then harrowed. Soybeans, cv Maple Arrow, were planted on 29 May 1981 and the land was uncropped in 1982 and 1983. The soil was a Guelph loam, pH 7.2, with approx. 3% organic matter content. The experimental design was a randomised complete block with four replications. The treatments included glyphosate (2.24 kg a.i./ha), sethoxydim plus adjuvant oil (1 kg a.i./ha plus 1% v/v) and haloxyfop-butyl plus oil (1 kg a.i./ha plus 1.25% v/v). All treatments, except glyphosate, were applied on 11 June 1981 to three leaf E. repens and cotyledon stage soybeans. Glyphosate was applied on 17 June 1981 to four leaf E. repens and unifoliate leaf stage soybeans. Shoot and rhizome material was collected from a 0.6 m^2 subplot five or six times per year in 1981, 1982 and 1983. Additional information can be obtained in Dekker (1984).

Experiment 2

A study was performed to assess the effects of three herbicides on rhizome bud viability when established under controlled conditions. The factorial arrangement of treatments included two bioassay techniques for assessing E. repens rhizome bud viability and three herbicide treatments: sethoxydim, haloxyfop-methyl and glyphosate. Systematic subsampling was performed on eight divisions of the rhizome system. The rhizome system divisions were determined by grouping the system into eight sections with equal numbers of rhizome nodes in each. The closest 12.5% of the nodes to the primary (treated) shoot were designated section 1, while the furthest, terminal 12.5% of the nodes from the primary shoot were designated section 8. The experimental design was a randomised complete block with five replications. Fourteen days after treatment each plant was unpotted, bud and shoot location were mapped and the rhizome system was divided into single bud sections. Each bud in the tetrazolium chloride bioassay was bisected longitudinally with a clean razor blade. Both halves were placed in a 10 ml vial with 5 ml of a 0.1% solution of water and 2,3,5-triphenyl tetrazolium chloride. Vials were incubated for exactly 22 h in the dark at 24° C. A pink or red stain in the meristem region at the node centre was evaluated as viable, while a white, unstained meristem was considered not viable. In the bud extension bioassay each 7.5 mm length bud was positioned vertically in the 3 ml well of a plastic culture plate filled with 2 ml agar. The midpoint of each rhizome node was at the agar surface level (Johnson and Buchholtz 1961). The 0.8% (wt/wt) agar was prepared in distilled water with 210 ppm KNO_3. The buds were evaluated every week for three weeks, any bud with evidence of growth was considered viable. Data presented are averaged over both viability assays. Complete experimental details can be obtained in Dekker (1985).

Experiment 3

The distribution of three ^{14}C-labelled herbicides in E. repens rhizomes was determined. Six-node rhizome segments were established in pots. The plants were grown under diurnal conditions of a 16 h and 20° C light period (approx. 450 μEm^{-2} sec^{-1}) and an 8 h and 15° C dark period approx. 50% R.H. Three, five and seven-leaf plants were later blocked for uniformity on the basis of pre-treatment rhizome node number and leaf stage. The experimental design was a 3 x 5 factorial arrangement of treatments in a randomised complete block with six replications. The treatment factors included two growth stages (five and seven leaf) and four chemicals (sucrose, glyphosate, sethoxydim and haloxyfop-methyl). The plants were first treated with 0.5 kg a.i./ha of the respective herbicides, and distilled water to the sucrose plants, to stimulate the physiolocy of a full-rate herbicide treated plant system. The ^{14}C herbicides were diluted in their formulated commercial analogues and distilled water (^{14}C-sucrose in distilled water with TWEEN 20^{TM} [non-ionic surfactant] at 0.1% v/v). These were then applied with a microsyringe at a rate of 400,000 disintegrations per minute (0.2 μCi) in 8 μl to the base of the newest fully expanded leaf of the first emerged (primary) shoot. Four days after treatment the treated leaf was washed with 95% ethanol and the wash collected. Five days after treatment the entire, intact plant system was unpotted, washed and freeze-dried. The plants from four replications were mapped and sectioned into primary (treated) shoot, secondary (untreated) shoots and individual rhizome nodes. These sections were then weighed, pelletted, combusted and counted by means of liquid scintillation. Plants from one replication were photographed by radioautography. Distribution of ^{14}C-labelled chemicals within plants was determined by grouping physiologically similar buds: new rhizome apical buds (terminal) were grouped together. Successively more basipedal nodes were grouped together also, up to the fifth bud from the rhizome tip. Additional experimental details are in Harker and Dekker (1984).

Experiment 4

Another experiment was conducted in 1984 to evaluate the effect of temperature and several herbicides on *E. repens* under similar conditions describted above for Experiment 3. The experiment was a randomised complete block design with a 3 x 7 factorial arrangement of treatments which included three temperature regimes and the four chemicals described in Experiment 3. Three and four leaf plants were blocked as above and placed in smaller, individual growth chambers set to three temperature diurnal (day/night) regimes; 30/25° C, 20/15° C and 10/5° C for seven days prior to treatment. Later, the plants were treated with 0.5 kg a.i./ha of commercially formulated herbicides and then the ^{14}C herbicides and sucrose (see Experiment 3 for details). Subsequent handling, data collection and analysis was as above. Additional experimental details are in Harker and Dekker (1985).

RESULTS AND DISCUSSION

Experiment 1. Field excavations

Untreated *E. repens* shoot dry matter increased from the spring into the summer, then declined into the autumn, in all three years (Fig. 1A). In 1982 a second period of increase in shoot dry matter occurred in the autumn. This was probably due to the longer growing season available in this noncrop year relative to 1981. Untreated rhizome dry matter declined from spring to summer in 1981 and 1983, probably due to mobilization and depletion of stored carbohydrates utilized for shoot growth at those times. In 1982 a steady increase in rhizome dry matter occurred as the growing season progressed. This could have been due to the extra soil nitrogen made available from the unharvested soybeans remaining from 1981. In all three years rhizome growth ceased from approximately mid July to early September or October. This phenomenon could be due to the mid-season heat and less favorable growth conditions during that period. In general glyphosate (Fig. 1A) and, possibly, sethoxydim (Fig. 1B) and haloxyfop-methyl (Fig. 1C) provided shoot and rhizome control for more than one season from a single application in May 1981. Shoot regrowth in the first, and subsequent years, was most evident in the sethoxydim treatment relative to the other herbicides. All herbicides provided long-term rhizome control in excess of that of the shoots.

Experiment 2. Controlled environment rhizome bud viability assessments

Rhizome bud viability of treated and untreated plants increased with increasing distance from the primary shoot (Fig. 2). All the herbicides reduced rhizome bud viability but none completely eliminated viable buds. These results indicate *E. repens* regrowth subsequent to treatment most likely would arise from dormant basal buds. Under the favourable temperature conditions (20/15° C) of this experiment, sethoxydim and haloxyfop-methyl provided better control of rhizome buds than glyphosate.

Experiment 3. Distribution of ^{14}C-compounds within new rhizome growth

Small amounts (approx. 6%) of applied ^{14}C-labelled compound translocated from the treated leaf into the rhizome system. Almost all of the compound in the rhizome system was found in new rhizome growth rather than in the original, propagating rhizome segment. Several patterns of ^{14}C-glyphosate accumulation and distribution within the rhizome system were observed (Fig. 3). An even gradient of ^{14}C-sucrose distribution in the terminal five rhizome buds was observed. ^{14}C-glyphosate accumulated to a greater extent in the terminal rhizome buds than those located more basipedally. The majority (45-55%) of the ^{14}C-sethoxydim accumulated in the apical tips, with less than 5% in the 5th bud from the terminus. ^{14}C-haloxyfop-methyl accumulated in the rhizome system in a pattern similar to sucrose. These results indicate a partial explanation of the differences observed in herbicide efficacy. Sethoxydim accumulates preferentially in rhizome tips and could be unavailable to more basipedal buds. Haloxyfop-methyl was distributed relatively equally between rhizome buds and could be available to more of the entire rhizome system.

Experiment 4. Temperature effects on the distribution of ^{14}C-compounds within *E. repens* plant parts

A temperature regime of 20/15° C was more favourable to rhizome growth than regimes of higher (30/25° C) and lower (10/5° C) temperatures. The relative amount of ^{14}C label that translocated to secondary untreated shoots compared to that moved into the rhizomes differed with changes in temperature (Fig. 4). As the temperature changed from 20/15° C to 30/25° C, ^{14}C-sucrose, glyphosate and haloxyfop-methyl distribution changed from equal amounts translocating to secondary shoots and rhizomes, to greater amounts translocating to secondary shoots relative to the rhizome system. A similar shift occurred between 10/5° C and 20/15° C with ^{14}C-sethoxydim distribution. Associated autoradiographs revealed that all compounds moved to some degree in both the xylem and phloem, with sethoxydim having the most pronounced apoplastic pattern of translocation. *E. repens* growth is much greater in the spring and autumn at the lower two temperature regimes studied here. Experiment 1 indicated that the highest temperatures studied here might be associated with heat-induced plant dormancy. The shift in chemical distribution from the rhizome system to untreated shoot portions of the same plant may be more important at the lower two temperatures than that between the higher two regimes. This factor could provide an explanation for the poorer efficacy of sethoxydim in the field relative to more favorable environments. Sethoxydim distribution away from the rhizome system occurs at a lower, more agriculturally relevant temperature than it does for the other herbicides. One hypothesis that is indicated by this work is that xylem movement, associated with higher transpiration rates, becomes more dominant than phloem movement as temperatures increase. Sethoxydim showed more pronounced apoplastic distribution with increases in temperature. This favours shoot accumulation over rhizome acculumlation.

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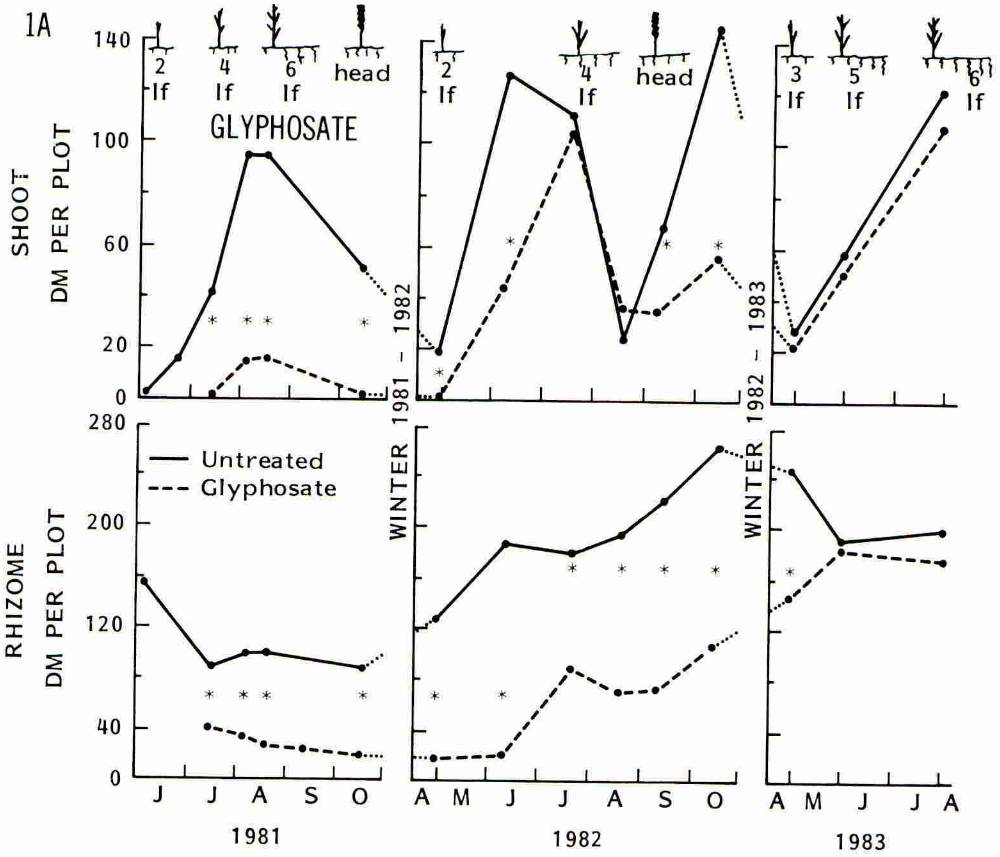
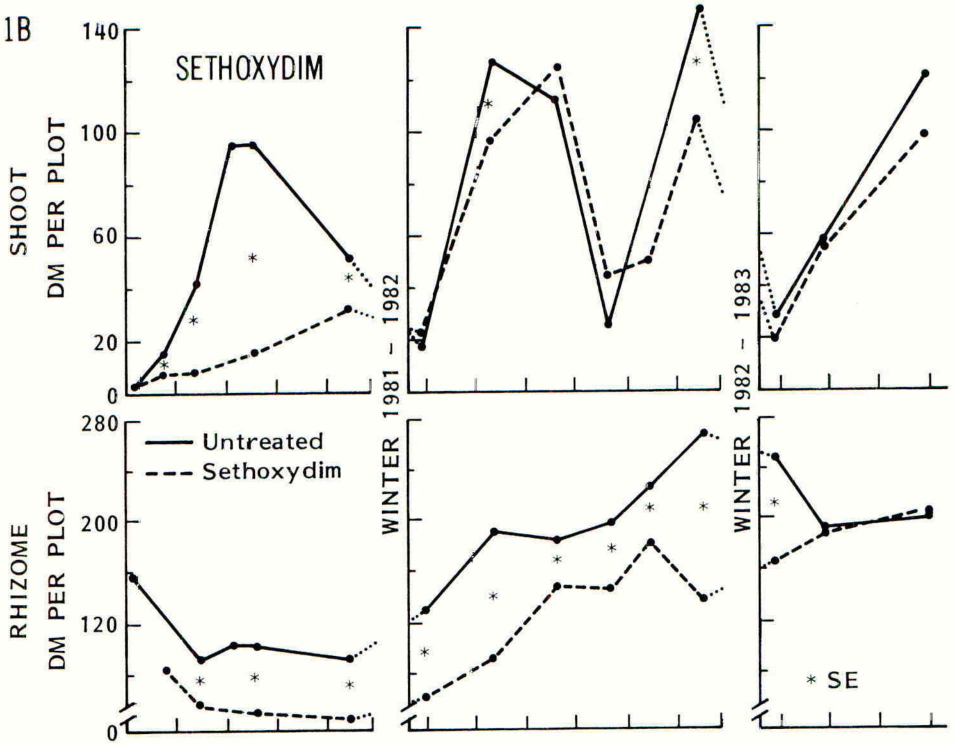
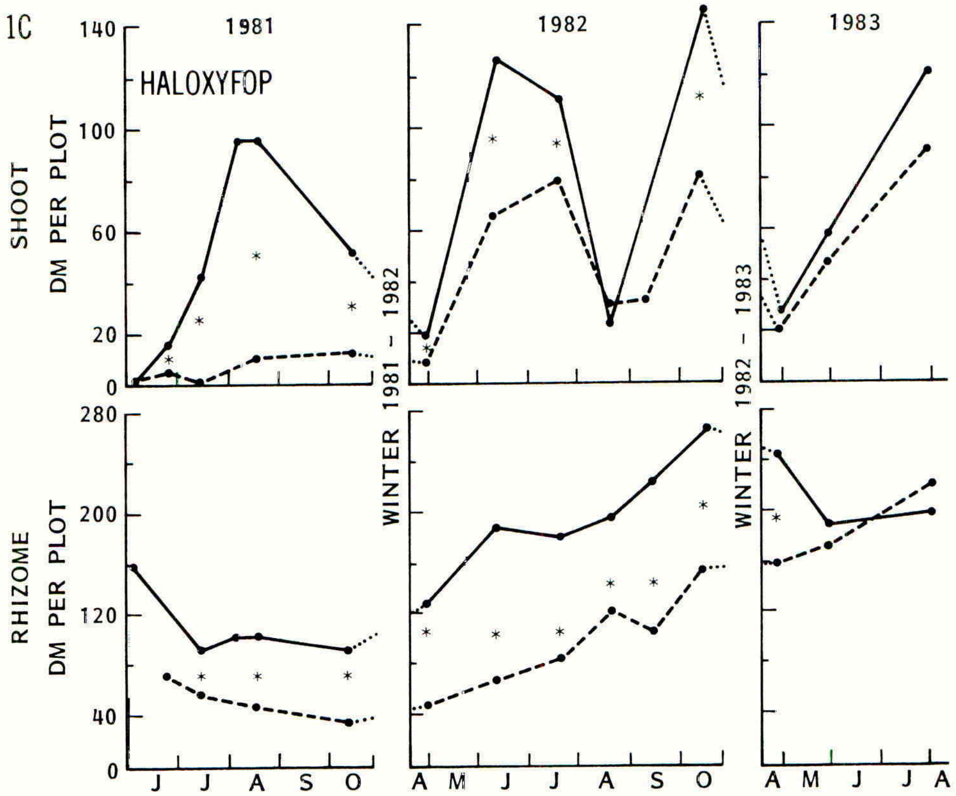


Fig. 1A - 1C. Effects of a single application of glyphosate (1A), sethoxydim (1B) and haloxyfop-methyl (1C) on E. repens shoot and rhizome d.m. per plot (0.6 m^2) from 1981 to 1983. "X" indicates that treated and untreated means S.E. are not coincident.

1B


SETHOXYDIM
SHOOT
DM PER PLOT
140
100
60
20
0
RHIZOME
DM PER PLOT
280
200
120
0
Untreated
Sethoxydim
WINTER 1981 – 1982
WINTER 1982 – 1983
* SE

1C


1981
1982
1983
HALOXYFOP
SHOOT
DM PER PLOT
140
100
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0
RHIZOME
DM PER PLOT
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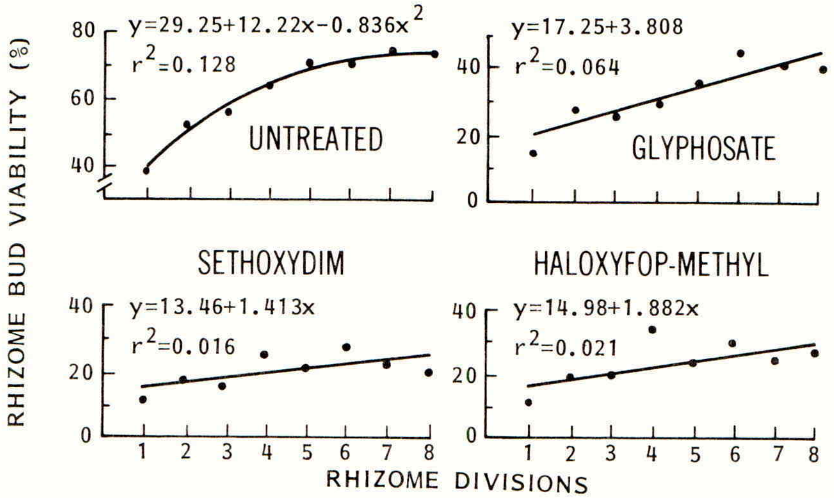

Fig. 2. Rhizome bud viability in different rhizome divisions (1=closest 12.5% of buds to treated shoot, 8=terminal 12.5% buds) of untreated and glyphosate, sethoxydim and haloxyfo-methyl treatments (means averaged over growth stage and bioassay technique of Experiment 2).

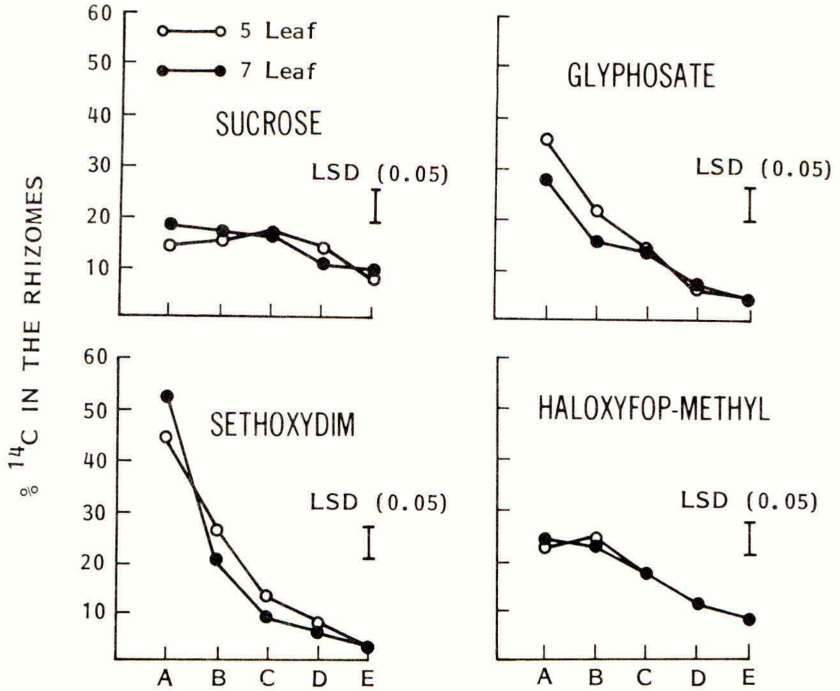

Fig. 3. Distribution of ^{14}C-sucrose, ^{14}C-glyphosate, ^{14}C-sethoxydim and ^{14}C-haloxyfop-methyl in rhizome buds; A=rhizome apical tip, E=5th rhizome bud from apical tip.

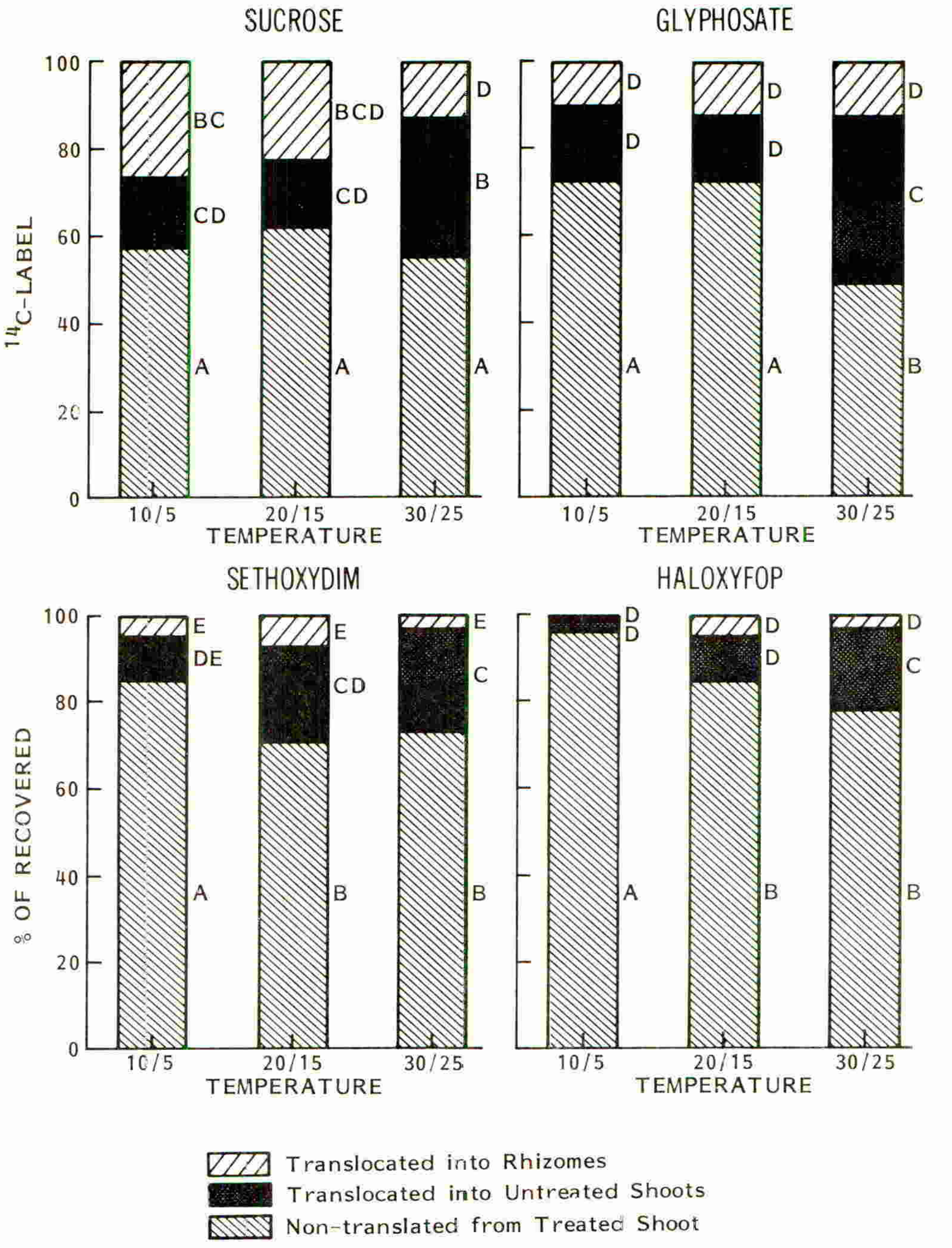

Fig. 4. Distribution of ^{14}C-sucrose, ^{14}C-glyphosate, ^{14}C-sethoxydim and ^{14}C-haloxyfop-methyl recovered from within three parts of treated E. repens plants established at three different temperatures: treated (primary) shoot, translocated to other (secondary) shoots or rhizomes. Means with the same letter are not significantly different according to Duncan's Multiple Range Test at the P=0.05 level of probability.