SESSION 8A

CEREALS (WEEDS AND WEED CONTROL)

CHAIRMAN MR J. H. BALDWIN

SESSION ORGANISER MR R. W. CLARE

INVITED PAPERS 8A-1 to 8A-10

INDEPENDENT EVALUATION OF CEREAL HERBICIDES IN GREAT BRITAIN: THE ROLE OF THE ADAS AGRICULTURE SERVICE

J. H. ORSON

ADAS/MAFF, Block B, Government Buildings, Brooklands Avenue, Cambridge CB2 2DR

ABSTRACT

The current state of independent evaluation of herbicides in Great Britain is discussed. The type of trials, trial numbers, trial methods, methods of dissemination of results are reviewed. Outside organisations' comments on the trials are considered, along with the adequacy of the number of trials carried out or demanded by various manufacturers or other official bodies.

It is concluded that the trials have been a reliable indicator of overall efficacy in the limited number of the major cereal crops that have been studied but the aspect of crop tolerance has not been adequately covered. Careful monitoring to explain the variation of herbicide performance may overcome some of the deficiencies in the number of sites. Whether or not governmental support for such work is reduced further, closer co-operation between various independent organisations is required to ensure that any chosen subject area is properly covered.

INTRODUCTION

The Agricultural Development and Advisory Service (ADAS) is part of and fully funded by the UK Ministry of Agriculture, Fisheries and Food.

ADAS and its predecessor the National Agricultural Advisory Service, which was founded in 1946, have, since their inception, studied weed control methods. Originally this included cultural measures of control but the evaluation of herbicides now accounts for 15% of the total resources devoted to development work in cereals by the Agronomy Department.

ADAS has maintained contact with other United Kingdom organisations that are involved in the independent evaluation of herbicides. The main vehicle for this has been the ADAS/Weed Research Organization Liaison Group where representatives of the Scottish Colleges and Department of Agriculture of Northern Ireland also attend. There has been an ADAS Liaison Unit at the Weed Research Organization.

The closure of the Weed Research Organization and the transfer of many of its responsibilities to Long Ashton Research Station is likely to lead to a reduction of the Agricultural and Food Research Council's (AFRC) effort into herbicide evaluation. Only about 15% of the AFRC crop protection budget is spent specifically on weed control. This, along with cuts in resources to ADAS and the Scottish Colleges, may mean significant reductions in independent evaluations of herbicides in the UK. It seems an opportune time to review what has been achieved in the past and to discuss the options for the future.

8A—1

ADAS HERBICIDE EVALUATION TRIALS

ADAS has regional centres with field teams and Experimental Husbandry Farms located throughout England and Wales. These provide the scope to evaluate herbicides in a wide range of environmental and cultural conditions. The trials are all of the complete randomised block design. Typically, a trial will have approximately fifteen treatments and three untreated controls. The treatments are applied with knapsack sprayers and yields are measured with a plot combine harvester.

Currently, all the trials are targeted against specific weeds. In recent years, Alopecurus myosuroides (black-grass), Bromus sterilis (barren brome), Poa species (rough and annual meadow grass), Galium aparine (cleavers), Viola arvensis (field pansy), Veronica hederifolia (ivy-leaved speedwell), Papaver rhoeas (common poppy), Matricaria species (mayweeds) and Elymus repens (common couch) have been the specified weeds. Some of the more common annual broad-leaved weeds inevitably occur in trials. From time to time weed free crop safety trials have been carried out. Treatments are co-ordinated by the ADAS herbicide Liaison Officer currently stationed at the Weed Research Organization.

It has long been accepted that only new active ingredients and unique combinations of active ingredients can be evaluated. To avoid testing an unnecessary number of development products, they are not introduced into trials until a year before marketing. In practical terms this means that recommended rates and timings are defined and the necessary clearances have been obtained. In addition, not all cereal crops are covered. Very little effort has been expended on spring barley in recent years. The trials in winter barley have also been reduced recently, partly because the competitive nature of the crop during earlier growth stages does not allow such a full expression of herbicide activity as in winter wheat.

The results of the trials are used immediately for field advisory work throughout the organisation. Notes describing the activity of new ingredients or unique combinations of active ingredients are sent to the general agricultural advisers. These notes are based not only on trials data but also on field experience, when available. Supporting data is not widely circulated as this can be open to misinterpretation if the full facts of each experiment are not known, but is made available to manufacturers with an interest in the herbicides used. Trial results are rarely averaged. The results are collated for ADAS annual reports on development work in cereals. Results also appear in papers presented to the British Crop Protection Conference - Weeds, held biennially, and at the appropriate conferences of the Association of Applied Biologists.

RECENT RESULTS OF ADAS TRIALS

Although herbicide evaluation has been the major reason for the trials, it has often not been the sole objective. The series on the control of annual broad-leaved weeds in the autumn or spring has provided long term information on the effect of the time of removal from winter cereals. In the mid-1970's, with their mild winters and dry springs, there was some yield advantage from removing annual broad-leaved weeds in the autumn rather than in the spring.

However, with a return to more "normal" weather, it has rarely happened since. These trials also showed that in the spring, the weeds should be sprayed prior to the first node detectable stage for efficacy as well as yield of grain (Evans & Harvey 1978, Bradford & Smith 1982).

When the yields of this series on annual broad-leaved weeds were studied, it was found that yield responses of winter barley growing on sandy soils were not as high as expected from the weed control obtained from autumn/winter applications of products based on mecoprop salt. This led to specific crop tolerance trials which indicated that mecoprop based products applied to winter barley grown on sandy soils may deleteriously affect yields. This work resulted in an appropriate label warning being placed on Approved mecoprop labels but importantly, it also showed that the crop tolerance to autumn/winter application was generally satisfactory (Orson 1983). Similar follow-up crop tolerance work has been carried out with spring applied herbicides for the control of Avena fatua in winter wheat.

The trials on the evaluation of herbicides for the control of A. myosuroides in winter cereals have also given valuable information on the time of their removal in respect of crop yield. These trials, from an initial stage in the early 1970's, showed that early post-emergence applications of isoproturon and chlortoluron often gave superior weed control and a trend to higher yields (Baldwin 1979). The results, along with those from the Weed Research Organization, encouraged investigation into low ground pressure vehicles, which preceded a significant shift to post-emergence rather than pre-emergence herbicide application. The ADAS trials also found that diclofop-methyl was not affected by herbicide adsorption on to organic matter of the soil or straw ash and trash. This discovery, backed up by invaluable research by the Weed Research Organization, has led to practical guidance on the identification of the problem and the necessary control measures required for A. myosuroides in such a situation (Moss 1984).

More recently, trials on the evaluation of herbicides for the control of G. aparine have also indicated the optimum environmental factors necessary for good control (Orson 1985).

A wide geographical spread of trials has been difficult to achieve. This is due, of course, to weeds being "regionalised"; A. myosuroides mainly occurring in the East and South East of England and Poa species in the North, West and South West of England. However, where a wide geographical spread has been possible some useful information has been gained. Trials have shown that chlorsulfuron does not provide reliable annual broad-leaved weed control on thin soils in high rainfall areas. In addition, higher yields from the autumn removal of annual broad-leaved weeds, when compared to spring removal, are more likely to occur in areas with milder winters.

Evaluation of herbicides for the control of 'new' weeds has also been carried out. Bromus sterilis (barren brome) began to appear as a signficant weed of winter cereals in the late 1970's. This was difficult to control with herbicides. The Weed Research Organization carried out a glasshouse screen and candidate herbicides were evaluated in ADAS trials. The most effective herbicides and herbicide sequences were identified (Orson 1981).

Phalaris paradoxa (awned canary-grass) became a local but potentially serious problem in winter cereals in the early 1980's. After a literature search of overseas information, candidate herbicides were evaluated in the field (Martindale & Livingston 1982).

CURRENT DEVELOPMENT OF TRIALS METHODS

As herbicides become more effective, it is more important to try to identify reasons for variation in performance between sites. Such information is invaluable when advising on herbicide selection. To this end, the recording of trials is becoming more complex. Already, all *A. myosuroides* sites are tested for the potential adsorption of herbicides.

Micro-electronics are also likely to help. Mobile weather stations are being evaluated for their use in identifying conditions for optimum activity of herbicides. Also, in common with many other organisations, field recording via portable computers is gradually being introduced. Not directly related to trials, but impinging on their worth, is the fact that data banks of field records are being considered. This would provide information on herbicide reliability. Computer models on the degradation of herbicides and leaching of herbicides may also help in explaining site variations, particularly when used along with time of weed emergence data.

The advent of possible herbicide tolerance is also impinging on evaluation. Seed of *A. myosuroides* is being collected from trial sites. This will be sown on a single site and cross sprayed with common treatments.

Differences in biomass of surviving weeds may not be related to the ability to set seed. This aspect has always been taken into account in trials on *A. myosuroides* and *A. fatua*, by making assessments of head-length/m^2 and panicle weight respectively. This aspect is now being considered for annual broad-leaved weed assessments.

COMMENTS FROM OTHER ORGANISATIONS OF THE VALUE OF THE TRIALS

Comments on the trials themselves are favourable. Herbicide manufacturers have welcomed the opportunity of a completely independent comparison of their herbicide made against a range of standards. Distributors and consultants welcome the opportunity to see the trials and to discuss the results and at demonstrations, farmers' comments are favourable. The Agricultural Chemicals Approved Scheme welcomes the opportunity to judge active ingredients and products against a range of standards rather than the one or two standards which they often see in manufacturers' trials.

There are criticisms; more of the use of the results than of the trials themselves. Making available results of individual trials has been severely criticised by some manufacturers. It is perhaps inevitable that such criticism is made because it places a huge responsibility on the adviser to ensure that the results are seen in the context of other trial results and the local scene as a whole. Equally, there is a danger of averaging the results of a number of trials; important variations may be missed and misleading information given. However, no manufacturers have mentioned this aspect, although it does explain the one or two instances where ADAS results have not appeared, on average, to reflect subsequent field performance. All manufacturers say that they admire the stand that ADAS has taken on the poor performance of some products. However, once again this puts the onus on the advisers to ensure that all aspects of the trials have been carried out in accordance with the requirements of the herbicide. The averaging of results often means that the true activity of a herbicide against certain weeds of a particuar size may be lost. Naturally, when products perform well, manufacturers are keen to use the results in publications, advertisements and presentations. When products do not perform well, there has been more criticism from the appropriate manufacturer. It must be emphasised that subjective assessments of commercial usage are also taken into consideration in ADAS comments on the activity of herbicides.

There are also criticisms of the weed assessments that are published. Autumn applications are assessed in the spring following treatment but often only the final early summer assessments are published. This is usually due to lack of space in the publications used by ADAS but individual trial reports, with full data, are available on request. When there is a lack of space, the final assessments give the greater guide to season-long control and are of particular value where different times of application are being compared. However, it is accepted that subsequent germination may occur after a foliar acting herbicide has been applied or a soil acting herbicide has degraded significantly. The different times of assessment have provided information on the persistence of weed control for soil acting herbicides.

There has been considerable criticism from herbicide manufacturers on the occasional inclusion of herbicides at reduced rates in the trials. The reason why reduced rates are included is two-fold. Firstly, there is no better way of understanding the strengths and weaknesses of a herbicide; an essential for any adviser. Secondly, there is the increasing likelihood of a clash between the label demands for reliable weed control of a high order and the agronomic demands of the farmer and the crop. The farmer is becoming more interested in managing weeds rather than controlling every last one now that he has accepted that the eradication of most weeds is an impossible objective. The results from lower than recommended rates are only discussed in scientific meetings or conferences.

DISCUSSION

In the 1985 harvest year, the number of ADAS trials on herbicide evaluation in cereals were:-

Control of *Poa* species in winter cereals - 9 trials

Control of annual broad-leaved weeds in the autumn of spring of winter cereals - 8 trials

Control of *A. myosuroides* with single applications of herbicides in winter cereals - 9 trials

Control of *A. myosuroides* with sequences of herbicides in winter cereals - 6 trials

Control of G. aparine in the early and late spring in winter cereals - 8 trials

There were other co-ordinated herbicide trials on the application of herbicides and long term trials on the effects of herbicide treatments of various intensities. In addition, some individual regions and Experimental Husbandry Farms had one or two trials with specific interest to their own locality.

These trials were nearly all carried out in winter wheat and so clearly, other cereals are not adequately covered.

The Scottish Colleges carried out in 1985 a series of trials on the control of Poa spp. and broad-leaved weeds. Eleven trials were completed on winter barley and one in winter wheat. In addition there were three evaluation trials on broad-leaved weed control in spring barley. The Weed Research Organization also provided data, particularly on A. myosuroides and G. aparine control but again did little work in cereals other than winter wheat and winter barley.

When new active ingredients are being developed by herbicide manufacturers, they tend to carry out at least ten efficacy trials/annum and an equal number of tolerance trials, for two to three years, in each major crop. The Agricultural Chemicals Approval Scheme likes to see, in winter cereals or spring cereals, ten to twelve trials/annum over at least two years for a new active ingredient. There should be a split between the crop species, efficacy and selectivity. A lower requirement of six trials/annum may be requested for a new product that is a novel mixture of established active ingredients. Evidence of varietal selectivity and soil persistence may be required.

If one draws a parallel with the testing of varieties the National Institute of Agricultural Botany (NIAB) carries out seven national list trials/annum for varieties of each major cereal crop. For recommended list trials, it has a minimum of ten to twelve trials/annum but would like to see around twenty trials/annum for each major crop spread throughout the main and appropriate cereal areas of England and Wales.

These facts show that independent evaluation trials have not covered all the major cereal crops adequately. In terms of efficacy this is not an important consideration for autumn sown crops as the majority of trials have been carried out in winter wheat, which is less competitive than winter oats or winter barley. However, there is little independent information on the efficacy of herbicides in spring sown crops. Therefore, whilst the information on efficacy provided may, in many cases, be comprehensive in winter cereals the crop tolerance data may be lacking.

It must be questioned whether, even for winter wheat that sufficient crop tolerance data has been obtained. Taking to yield efficacy trials may identify, and in fact have identified, some crop tolerance problems. However, a comprehensive series of specific crop tolerance trials are required to measure any possible small effects on yields. Independent organisations in Europe put a great emphasis on this aspect as well as efficacy. There is more than some credibility in the argument that ADAS should carry out simpler efficacy trials and introduce specific crop tolerance trials. However, very careful consideration of the value of specific tolerance trials is required. Small yield decreases may never be identified within acceptable statistical confidence levels.

It should be emphasised that only new active ingredients or novel combinations of active ingredients are evaluated in ADAS trials. Different formulations of the same active ingredients or tank-mix alternatives may produce different results.

Therefore, it has been clearly demonstrated that the level of resources invested in independent trials is insufficient in order that a "recommended list" of herbicides could be published in a similar way to that for cereal varieties by the NIAB. ADAS in some of its publications does give efficacy ratings for major active ingredients, but this is only after testing over a fair period of time - usually three to four years.

The new legislation being introduced under Part III of the Food and Environment Protection Act will require the presentation of efficacy data in support of registration. Regulations resulting from the Act could prohibit the sale of products until testing has been completed, whether it was carried out by the manufacturer or by independent evaluation. Without this safeguard, all the manufacturer would have to do would be to produce a slight change in a formulation in order to say that the current product is different (and better) than the "old" product that was tested.

The need for an extensive independent evaluation scheme in Great Britain - a NIAB for herbicides? - or whether we can have a really effective registration scheme without independent evaluation of products is debatable. The manpower of the Pesticide Registration and Surveillance Department is being increased but not to the extent that field trials can be carried out. Unlike varieties, the efficacy of herbicides is more assessable in the field; weeds die or they do not. Therefore, with advisers walking fields, a good idea of efficacy can be obtained. The development of computer data banks of field records could aid this process. Such a system of field efficacy assessment is ideal for getting an estimate of reliability because it is obvious that more fields can be sprayed than trials carried out! However, there are shortcomings to such an approach: new active ingredients cannot be assessed in such a way and also, the relative differences between products are very hard to quantify.

It is unlikely that governmental resources will be made available for a complete and comprehensive independent assessment of herbicides. In addition, it can be argued that the imposition of such a condition could "straight-jacket" the industry and reduce its flexibility and progress. Also, with such a range of weeds and conditions encountered, any "recommended list" in the style of those produced for varieties could be too complex for anyone to understand! This latter comment may be an attitude of defeatism and that the computer could help in this complex situation.

On the other hand, it is clear that many farmers are using the wrong herbicide for a given situation and/or spending too much on weed control. Such a "recommended list", if it could be simplified, would be of benefit to these farmers. The publication of a list of all registered products and their approved uses under the new legislation will be a foundation on which even more useful publications could be based.

In conclusion, current independent evaluation of herbicides has provided reliable information on the efficacy of the major active ingredients and some novel combinations of active ingredients in winter cereals. This has enabled ADAS advisers to stand on a public platform to give positive advice on the relative merits of herbicides. Without such data and first hand experience of seeing products side by side, this would be impossible. However, it is clear that more information is required on the control of weeds in spring crops and crop tolerance of all cereal crops. The aspect of crop tolerance will become more important in the future as a range of very effective herbicides become available to the farmer. Also, it has to be accepted that there is no information on the relative merits of different formulations of the same active ingredients.

Careful monitoring of factors affecting herbicide performance and data banks of field records may overcome an apparent shortage of sites on the efficacy of herbicides. This may even release some resources for investigations into crop tolerance. The spread of sites has to be carefully considered, not necessarily for an even geographical spread, but from the point of view of conditions that may effect herbicide efficacy and reliability. This aspect already receives greater emphasis than in the post.

In addition, the "consumer demand" for information, as well as ADAS requirements, has to be considered. Outside bodies do seem to ask for more standards than ADAS often likes to include. Once again, it should be stressed that the trials are to study new active ingredients, novel combinations of active ingredients or active ingredients in specific situations, rather than to provide a demonstration of the "state of the art" of herbicide industry. Under impending legislation, manufacturers will have to provide evidence of efficacy in addition to the safety data currently demanded for registration. At the present time only some 600 out of the 3000 pesticides on sale have been evaluated for efficacy by the voluntary Agricultural Chemicals Approved Scheme, and the increased workload required to assess all pesticides may mean that a lower proportion of manufacturers' trials will be visited. This suggests that independent data will be of increased value in the registration of herbicides.

It is clear that great care should be taken in the handling of and drawing conclusions from the data provided. ADAS is only too aware that it is commenting on herbicides that may have cost millions of pounds to develop.

There should be a continuing reassessment of how the independent trials are reflecting not only the demand for information but also the likely future demand from new cropping systems. This reassessment will often depend on new herbicides being introduced for a weed that is or is not being currently investigated. Such an example is A. fatua which has no specific trials because there have been no recent herbicide introductions.

There has to be the closest collaboration possible between independent bodies. This may involve the swallowing of some pride but individual trials are not going to provide a great deal of useful information! It is important that each aspect is investigated comprehensively rather than the whole subject is tackled in an individual and fragmented way. This aspect is of critical importance whether or not governmental support for such work is reduced further.

The people who gain by independent testing, ie. the farmer by use and the manufacturer by sales, may have to consider some financial support for the independent testing of herbicides if a sophisticated and comprehensive system is deemed to be necessary.

REFERENCES

Baldwin, J.H. (1979) The chemical control of wild-oats and black-grass - a review based on results from ADAS agronomy trials. ADAS Quarterly Review 33, 69-101.

Bradford, A.M.; Smith, J. (1982) Annual broad-leaved weed control in winter cereals - ADAS 1982 results. Proceedings British Crop Protection Conference - Weeds 2, 539-544.

Evans, S.A.; Harvey, J.J. (1978) Annual broad-leaved weed control in winter wheat - autumn and spring treatments compared. Proceedings British Crop Protection Conference - Weeds 1, 41-47.

Martindale, J.F.; Livingston, D.B. (1982) Chemical control of Phalaris paradoxa in winter cereals. Proceedings British Crop Protection Conference - Weeds 2, 671-675.

Moss, S.R. (1984) The influence of cultural practices on the activity of soil-acting herbicides. British Crop Protection Council Monograph 27 - Soil and Crop Protection Chemicals, 77-86.

Orson, J.H. (1981) The control of Bromus sterilis in cereals with herbicides - Agricultural Development and Advisory Service Results 1979 and 1980. Proceedings of Association Applied Biologists Conference - Grass Weeds in Cereals in the United Kingdom, 291-298.

Orson, J.H. (1983) The effect of time of application on the tolerance of winter barley to mecoprop and/or bromoxynil with ioxynil. Aspects of Applied Biology, 3 - Crop Sensitivity to Herbicides, 135-144.

CONTROL OF ALOPECURUS MYOSUROIDES (BLACK-GRASS) IN WINTER CEREALS WITH ISOPROTURON - A SUMMARY OF TRIALS CARRIED OUT OVER TWELVE YEARS IN THE U.K.

R.T. HEWSON, M.A. READ

Hoechst U.K. Limited, Agriculture Division, East Winch Hall, East Winch, King's Lynn, Norfolk, PE32 1HN, England

ABSTRACT

A total of 633 trials was carried out during the harvest years 1973 to 1984 with isoproturon applied as it is currently recommended for the control of *Alopecurus myosuroides*. On average, a 94% reduction in the number of seed heads was obtained following pre-emergence application, 95% from spraying early post-emergence, 91% from spring treatment up to the early-tillering stage of *A. myosuroides* and 73% following application made later than this up to the booting stage of the weed. However, good control was still obtained from late spring applications provided the soil was moist. Chlortoluron tended to give lower levels of control than isoproturon, particularly with post-emergence applications. Early weed removal was reflected in higher yield responses, and higher yields also resulted from removal of larger populations of the weed. Soil types encountered in these trials had little influence on levels of *A. myosuroides* control. Although isoproturon was very effective when applied over a six-month period from autumn through to early spring, for optimum yield responses to be achieved it is concluded that this weed should be removed during the autumn/winter.

INTRODUCTION

One of the most important grass weeds of winter cereals is *Alopecurus myosuroides* (black-grass). An early paper (Long 1929) indicated the enormous potential of *Alopecurus agrestis* (= *A. myosuroides*) to drastically affect the yield of winter cereals. Although it has two peaks of germination (Thurston 1972), autumn and spring, the more important peak in winter cereals is likely to occur in autumn. This gives rise to an early competitive influence of the weed in these crops. *A myosuroides* seeds germinate close to the soil surface and cultural techniques, such as minimum cultivation, which retain seeds close to the surface result in higher infestations.

The mechanical methods for control of *A. myosuroides* advocated by Long (1929) have since been replaced by chemical treatments. Although short persistence herbicides, such as terbutryne or metoxuron, applied in the autumn gave some control they tended to miss the spring-germinating weeds. Also, spring-applied herbicides such as barban, controlling only seedling *A. myosuroides*, were not effective against well-tillered autumn-germinating plants. These herbicides, together with cultural methods of control involving spring cropping, late drilling of winter cereals and more regular rotational "breaks" were only a partial remedy and have gradually been superseded by more effective herbicides. One of the most successful of these is isoproturon.

The chemical structure, physical and toxicological properties of isoproturon, a substituted phenyl urea, were first described by Rognon *et al.* (1972). Thizy *et al.* (1972) also reported selective control of *A. myosuroides*, other annual grasses, and some broad-leaved weeds pre- and post-emergence in wheat. Initial field trials with isoproturon carried out in the U.K. were reported by Hewson (1974).

Although primarily developed for control of A. myosuroides, the chemical has successfully been used in tank-mixtures (Black & Hewson 1982) and as formulated products (Brain et al. 1982) with other herbicides to extend the broad-leaf weed spectrum. Rates of a.i. lower than those adopted for A. myosuroides have also been used effectively for control of Poa spp. (Hewson & Read 1985).

Isoproturon may be applied pre- or post-emergence. The main route of uptake appears to be the soil, even from post-emergence applications, although Blair (1978) suggests that foliar uptake may be important under certain environmental conditions.

The object of this paper is to review the field trials carried out by Hoechst U.K. Limited during the harvest years 1973 - 1984 with isoproturon, applied as in current commercial practice, for control of A. myosuroides.

MATERIALS AND METHODS

All trials were carried out on commercial crops of winter wheat or winter barley in England, covering a wide range of locations, soil types and cultivars. Application to sites with high organic matter content was made in spring only, as recommended. The trials were designed as randomised blocks with three replicates and a plot size of 10 - 15 m^2. Applications were made using hand-held Van der Weij 'AZO' small-plot precision sprayers at a pressure of 250 kPa delivering 200 (8001 Tee Jet), 300 (80015 Tee Jet) or 400 (8002 Tee Jet) l/ha through eight spray nozzles, spaced 25 cm apart, on 2 m spray booms.

A total of 633 trials was carried out during harvest years 1973 to 1984. Of these, 169 were sprayed pre-emergence, 150 early post-emergence (up to the end of December; Alopecurus myosuroides GS (Zadoks et al. 1974) 11 - 23), 131 in early spring up to the early-tillering stage (GS 12 - 23) of A. myosuroides and 183 in late spring beyond this stage (GS 24 - 46).

Isoproturon (as ®Arelon) was applied as a 75% w.p., 500 or 553 g/l a.c. The recommended rate of 2.5 kg/ha a.i. was applied pre- or early post-emergence up to the end of December and 2.1 kg/ha a.i. after the 1st of January in each year. Corresponding rates of chlortoluron (80% w.p. or 500 g/l a.c.) were 3.5 and 2.75 kg/ha a.i. A. myosuroides was assessed by counting seed heads, as soon as all had emerged, in random quadrats which varied in size from 0.1 to 0.5 m^2 according to the density of A. myosuroides. Crop yields were taken using Hege small-plot combine harvesters.

RESULTS AND DISCUSSION

Annual and seasonal variation in control of A. myosuroides as influenced by climatic conditions

Results are presented separately for pre-emergence, early post-emergence, early- and late-spring applications in each of the harvest year's trials were carried out (Table 1). Although high levels of control were obtained with pre-emergence (mean of 94%), early post-emergence (95%) and early-spring (91%) applications, the early post-emergence timing tended to give the most consistent results. To be effective isoproturon must move down into the soil to be taken up by the root system which develops at or below seed level (Blair 1978). Blair (1985) also reported that activity

TABLE 1

Annual and seasonal variation in the % control of _Alopecurus myosuroides_

Harvest year	Isoproturon				Chlortoluron		
	Pre-em.	Early post-em.	Early spring	Late spring	Pre-em.	Early post-em.	Early spring
1973	95 (17)	100 (2)	94 (19)	-	96 (17)	100 (2)	89 (19)
1974	96 (10)	-	91 (13)	-	96 (10)	-	78 (10)
1975	91 (3)	93 (9)	93 (9)	81 (12)	81 (3)	90 (9)	82 (2)
1976	92 (15)	94 (6)	58 (3)	69 (32)	93 (6)	67 (6)	
1977	85 (9)	90 (3)	100 (3)	81 (24)			
1978	90 (6)	96 (19)	89 (5)	68 (9)			
1979	93 (17)	90 (9)	98 (23)	95 (8)			
1980	93 (17)	95 (7)	91 (10)	66 (36)	83 (12)		
1981	96 (18)	94 (11)	94 (26)	93 (8)	89 (8)		
1982	97 (24)	99 (12)	70 (5)	74 (31)	96 (6)		
1983	97 (21)	95 (47)	91 (4)	77 (5)	97 (21)	95 (34)	
1984	92 (12)	92 (25)	82 (11)	61 (18)	81 (10)	85 (11)	
MEAN	94 (169)	95 (150)	91 (131)	73 (183)	92 (93)	90 (62)	85 (31)

Figures in parenthesis refer to numbers of trials.

following post-emergence application of isoproturon increased with increasing amounts of water applied to the soil. Early post-emergence applications, which were usually made in November and December, are more likely to encounter conditions in which this can occur resulting in more consistent control. Previous work (Hubbard et al. 1976) has also shown that early post-emergence application gave better control of A. myosuroides than pre-emergence treatment. Of the pre-emergence applications, slightly lower levels of control were obtained over the period 1975 - 1978 and in 1984. Early autumn of the harvest years 1975, 1976, 1977 and 1984 tended to be wet (Table 2) and it appeared that applications made under these conditions resulted in loss of residual activity (of both isoproturon and chlortoluron) which is needed to control spring-germinating A. myosuroides. However, the exceptionally dry September and October of harvest year 1978 appears to have been the cause of the slightly lower level of control which was obtained.

TABLE 2

Monthly rainfall figures for East Anglia as a % of the long term monthly average

Harvest year	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1973	75	15	87	84	29	54	41	118	151
1974	139	66	47	64	87	143	72	28	40
1975	175	188	175	59	135	55	210	145	130
1976	177	33	95	58	72	43	34	38	60
1977	171	178	108	108	125	193	110	74	88
1978	31	43	94	107	135	115	141	113	111
1979	60	11	39	190	122	137	220	138	172
1980	38	93	82	178	75	114	152	56	35
1981	60	149	79	77	75	59	234	171	150
1982	141	132	60	91	73	47	135	34	125
1983	94	230	117	100	84	99	92	235	206
1984	121	74	77	78	163	90	115	33	159

Dry conditions also appear to be the cause of the reduced activity with early-spring applications in 1976 and 1982. Variation in the level of control with late-spring applications resulted from a combination of weed size (see below) and climatic conditions. The very wet springs of 1979 and 1981 enabled A. myosuroides to be controlled up to the end of tillering, whereas such large plants were less affected under drier conditions (e.g. 1976 and 1980).

Although chlortoluron was not included in all of the trials there was a tendency for control of A. myosuroides to be less effective than with isoproturon, particularly with post-emergence applications (Table 1). During the twelve seasons over which trials were conducted there was no indication of resistance of A. myosuroides to isoproturon as suggested by Moss & Cussans (1985).

Effect of time of application on a calendar basis on control of A. myosuroides

Applications of isoproturon were made over a nine-month period during harvest years 1973 to 1984, and the effects of these different times of application on A. myosuroides control are summarised in Table 3. Good control of A. myosuroides was obtained throughout the period September to early March, covering pre-emergence, early post-emergence and early spring applications (see Table 1). Thereafter the level of control was reduced, brought about by a combination of weed size and drier spring conditions.

TABLE 3

Effect of time of application on a calendar basis

Month	% control of A. myosuroides		Relative crop yield (untreated = 100)	
	Mean	No. of trials	Mean	No. of trials
September	93	33	161	14
October	95	171	150	81
November	93	91	158	47
December	92	27	148	19
January	96	15	142	12
February	90	54	138	26
March	80	119	137	68
April	82	112	123	45
May	71	11	118	3

Effect of A. myosuroides growth stage at application

Applications made pre-emergence or post-emergence up to the early-tillering stage of A. myosuroides resulted in good control being obtained (Table 4). At later growth stages the mean level of control was more

TABLE 4

Effect of growth stage at application on control of A. myosuroides

A. myosuroides GS	Mean % control	Range of control	No. of trials
0 - 10	93	44 - 100	168
11 - 14	95	69 - 100	146
21 - 23	90	12 - 100	140
24 - 26	73	0 - 100	77
27 - 29	79	11 - 100	54
30	70	20 - 100	31
31 - 46	64	3 - 89	17

variable, although good results were still obtained (shown by the range of control values given in Table 4) at later growth stages in seasons when this coincided with moist soil conditions. Climatic conditions were thus felt to be more important than the actual size of A. myosuroides at application.

Effect of time of A. myosuroides removal on crop yield

A total of 315 trials was harvested. The relative crop yields (untreated = 100) obtained from pre-emergence, early post-emergence, early and late spring applications were 157 (mean of 80 trials), 151 (78), 136 (73) and 129 (84), respectively. Those for applications made on a calendar basis have been included in Table 3. Yield responses from removing A. myosuroides at different times thus tended to be higher the earlier treatment was carried out. Wilson et al. (1985) also found that delaying A. myosuroides removal from November until April resulted in yield responses of about 60% and 20%, respectively. It is clear that competition between A. myosuroides and cereals starts early in the season and for maximum yields to be obtained this weed should be controlled during the autumn/winter period.

Effect of A. myosuroides density on crop yield response

Most of the trials had A. myosuroides at densities of between 51 and 800 seed heads/m^2 (Table 5). In addition to time of application, the density of the weed population removed is also likely to influence the yield response. This was in fact the case for A. myosuroides densities of 101 - 1,600 seed heads/m^2 where the higher the density the greater the yield response obtained at each application timing. With A. myosuroides densities of $<$50 and 51 - 100 seed heads/m^2 similar yields were obtained. Above 1,600 seed heads/m^2 the results were somewhat variable due to the low numbers of trials in this category.

Effect of soil type

Most trials were carried out on clay loam (29% of all pre-emergence, early post-emergence and early-spring trials) or sandy clay loam (45%) soils, although other soil types were encountered covering light, medium, heavy and very heavy textural groups. The results did not indicate that A. myosuroides control was greatly influenced by any particular soil type, although it tended to be better on very heavy (mean of 98%, 14 trials) than on lighter soils (heavy 93%, 252 trials; medium 94%, 145 trials; light 91%, 10 trials). Cussans et al. (1982) also found no clear relationship between soil textural class and isoproturon performance.

ACKNOWLEDGEMENTS

The authors would like to thank the many farmers who kindly provided trials sites. We would also like to thank Mr. E. Spackman of the Agro-meteorology Department of ADAS for the weather data, Mr. S. Ng and Ms. E. A. Norland for help with the computer analysis of the data and our colleagues in the Technical Department of Hoechst U.K. Limited for their invaluable assistance.

REFERENCES

Black, I.A.; Hewson, R.T. (1982) Weed control with ioxynil plus bromoxynil alone and in tank-mixture with other herbicides applied in the autumn/winter. Aspects of Applied Biology 1. Broad-leaved weeds and their control in cereals, 87 - 95.

TABLE 5

Effect of *Alopecurus myosuroides* density and time of removal on crop yield response

A. myosuroides seed heads/m^2	Relative yield (untreated = 100)									
	Pre-em.		Early post-em.		Early spring		Late spring		All timings	
	Mean	No. trials	Mean	No. trials	Mean	No. trials	Mean	No. trials	Mean	No. trials
0 - 50	119	9	131	6	118	6	106	5	119	26
51 - 100	117	15	109	12	121	21	123	14	118	62
101 - 200	134	13	138	21	118	17	111	18	125	69
201 - 400	144	12	158	12	129	13	124	18	137	55
401 - 800	154	20	167	16	174	10	131	17	154	63
801 - 1600	304	8	197	10	208	2	245	6	242	26
1601 - 3200	249	3	262	1	205	4	139	6	190	14
MEAN	157	80	151	78	136	73	130	84	144	315

Blair, A.M. (1978) Some studies on the sites of uptake of chlortoluron, isoproturon and metoxuron by wheat, Avena fatua and Alopecurus myosuroides. Weed Research 18, 381 - 387.

Blair, A.M. (1985) Influence of soil moisture on isoproturon activity against Alopecurus myosuroides. Weed Research 25, 141 - 149.

Brain, P.J.; Hewson, R.T.; Rea, B.L.; Marshall, J. (1982) New formulated mixtures based on isoproturon for annual weed control in cereals. Proceedings British Crop Protection Conference - Weeds 2, 515 - 521.

Cussans, G.W.; Moss, S.R.; Hance, R.J.; Embling, S.J.; Caverley, D.; Marks, T.G.; Palmer, J.J. (1982). The effect of tillage method and soil factors on the performance of chlortoluron and isoproturon. Proceedings British Crop Protection Conference - Weeds 1, 153 - 160.

Hewson, R.T. (1974) Isoproturon, a new selective herbicide for control of Alopecurus myosuroides in winter cereals. Proceedings 12th British Weed Control Conference 1, 75 - 82.

Hewson, R.T.; Read, M.A. (1985) Control of meadow-grasses and broad-leaved weeds in cereals with post-emergence isoproturon mixtures. Aspects of Applied Biology 9. The biology and control of weeds in cereals, 245 - 254.

Hubbard, K.R.; Livingston, D.B.; Ross, B.L. (1976) Chemical control of Alopecurus myosuroides in winter cereals. Proceedings British Crop Protection Conference - Weeds 1, 63 - 70.

Long, H.C. (1929) Weeds in Arable Land. HMSO, London 127.

Moss, S.R.; Cussans, G.W. (1985) Variability in the susceptibility of Alopecurus myosuroides (black-grass) to chlortoluron and isoproturon. Aspects of Applied Biology 9. The biology and control of weeds in cereals, 91 - 98.

Rognon, J.; Thizy, A.; Poignant, P.; Pillon, D. (1972) Essais de désherbage des céréales avec la N-(isopropyl-4-phényl)-N', N'-diméthylurée. Proceedings Ghent Symposium on Crop Protection, 663 - 669.

Thizy, A.; Pillon, D.; Poignant, P.; Rognon, J. (1972) Activité herbicide sélective de la N-(isopropyl-4-phényl)-N', N'-diméthylurée. C. R. de l'Academie des Sciences de Paris 274 Serie D, 2053 - 2056.

Thurston, J.M. (1972) Black-grass (Alopecurus myosuroides Huds.) and its control. Proceedings 11th British Weed Control Conference 3, 977 - 987.

Wilson, B.J.; Thornton, M.E.; Lutman, P.J.W. (1985) Yields of winter cereals in relation to the timing of control of black-grass (Alopecurus myosuroides Huds.) and broad-leaved weeds. Aspects of Applied Biology 9. The biology and control of weeds in cereals, 41 - 48.

Zadoks, J.C.; Chang, T.T.; Konzak, C.F. (1974) A decimal code for the growth stages of cereals. Weed Research 14, 415 - 421.

®Registered trade mark of Hoechst

PENDIMETHALIN AND ISOPROTURON COMBINATIONS: A FIELD ASSESSMENT OF EFFICACY AND CROP TOLERANCE IN WINTER CEREALS

E. J. GUSSIN, J. C. EVANS

Cyanamid of Great Britain Limited, Fareham Road, Gosport, Hampshire, UK

ABSTRACT

The efficacy and crop safety of tank mix combinations of pendimethalin and isoproturon applied to winter cereals were investigated in 45 trials in the UK. The optimum combination of doses of 1.3 kg a.i./ha of each component was identified, and superior weed control was obtained using this treatment in comparison to that obtained with standard doses of either pendimethalin or isoproturon alone. The combination was more effective on grass weeds than pendimethalin alone and more effective on broad-leaved weeds than isoproturon alone. Significant increases in yield over untreated plots were demonstrated and no adverse crop effects were observed. This mixture is therefore a significant improvement for broad spectrum weed control in cereals over either herbicide applied alone.

INTRODUCTION

Control of mixed infestations of broad-leaved weeds and grass weeds in cereals often require the application of more than one chemical in sequence and can frequently be hindered by poor weather conditions at optimum application times. A herbicide or herbicide combination with flexibility in timing of application and a broad spectrum of weed activity is therefore preferred.

Pendimethalin is widely used under the trademark 'STOMP', and is a soil acting herbicide for pre-emergence control of *Alopecurus myosuroides*, *Poa annua* and broad-leaved weeds. Isoproturon is a translocated and soil acting herbicide for pre or post-emergence control of black-grass, other annual grass weeds, and broad-leaved weeds.

The two herbicides, used alone, also have weed control properties which are complementary and therefore a combination of these compounds should provide a broader spectrum of control than either of the components with pre- or post-emergent treatments.

A total of 40 small plot replicated trials were carried out in the UK between 1982 and 1985 to determine the efficacy and crop safety of pendimethalin and isoproturon combinations in winter wheat and winter barley.

MATERIALS AND METHODS

Field trials were carried out on commercially grown crops and all treatments were made in 200 l/ha water using a carbon dioxide pressurised small plot precision sprayer at 280 kPa.

Efficacy trials were in areas of natural weed populations, with plots 2 x 8 metres and 3 replicates in randomised block design. A mixture of pendimethalin and isoproturon both at 1.3 kg a.i./ha was tested pre and post-emergence of the crops and weeds, up to early tillering of grass weeds and four true leaves of broad-leaved species. This was compared to 2.0 kg a.i./ha pendimethalin or 2.5 kg a.i./ha isoproturon, each applied alone. Broad-leaved weeds were counted in quadrats in untreated plots to establish population numbers, and visual estimates were made of weed control in treated plots. Grass weed numbers were counted using quadrats in all plots from which percent control was calculated. In the case of wild-oats (*Avena fatua*), estimates of reduction in spikelets were made using the method described by Holroyd (1968). Three sites with weed infestations were harvested using a small-plot combine, enabling grain yield comparisons between treated and untreated plots.

Trials designed to investigate crop tolerance were conducted in weed-free crops where twice the normal doses of pendimethalin and isoproturon (2.6 + 2.6 kg a.i./ha) were applied post-emergence. These trials had plots measuring 3 x 15 metres and 4 replicates in randomised block design. All efficacy and crop tolerance trials were monitored for visible effects on crops throughout the growing season. Tolerance was assessed visually as percentage reduction in crop vigour compared to untreated plots. Six trials at weed free sites were harvested to determine grain yields.

RESULTS

(i) Efficacy

In earlier trials comparing different dose combinations of pendimethalin and isoproturon it was determined that 1.3 + 1.3 kg a.i./ha was the optimum dose for weed control and crop safety.

The pre-emergence combination treatment was generally more effective than the post-emergence treatment and, in the case of *Matricaria*, comparable results were obtained by both methods of application (Table 1). Either pre or post-emergence applications of the combination gave better average weed control than isoproturon or pendimethalin applied alone at their recommended rates. In comparison to isoproturon applied alone at 2.5 kg a.i./ha, the combination was slightly less effective against black-grass (*A. myosuroides*), but more effective against wild-oats (*A. fatua*). Efficacy on broad-leaved weeds was generally equal to or better than that achieved by either of the products applied alone.

TABLE 1

Weed control with pendimethalin and isoproturon applied either alone or in combination

pendimethalin (kg ai/ha):	1.3	1.3	2.0	-	-
isoproturon (kg ai/ha):	1.3	1.3	-	2.5	2.5
application time:	pre	post	pre	pre	post
weed species	mean % control (no. of sites)				
Alopecurus myosuroides	94 (9)	87(20)	85 (8)	97 (5)	90(21)
Avena fatua	-	92 (5)	-	-	85 (5)
Poa trivialis	96 (1)	-	-	-	99 (1)
Aphanes arvensis	99 (2)	-	100 (2)	55 (2)	-
Galium aparine	100 (2)	75 (2)	95 (2)	87 (2)	28 (2)
Matricaria sp	90 (1)	100 (2)	73 (1)	-	100 (1)
Myosotis arvensis	100 (2)	71 (1)	100 (2)	94 (2)	67 (1)
Stellaria media	100 (3)	-	95 (3)	87 (3)	-
Veronica hederifolia	98 (1)	-	100 (3)	30 (1)	35 (2)
Veronica persica	98 (2)	100 (2)	98 (2)	93 (1)	46 (2)

TABLE 2

Effect on grain yield at weed-infested sites pre- and post-emergence applications of pendimethalin and isoproturon (as % of untreated)

pendimethalin (kg a.i./ha):		-	1.3	2.0	-	
isoproturon (kg a.i./ha):		-	1.3	-	2.5	S.E.M.
Winter barley	post-emergence	100	171(1)	125	216(1)	22.5
Winter wheat	pre-emergence	100	139(2)	129(1)	123(1)	13.9
	post-emergence	100	164(1)	146	167(1)	7.2

( ) indicates number of trials

The combination produced considerable grain yield increases at weed infested sites, comparable to those obtained from either component used alone (Table 2). Consideration should be given, however, to the small plot size and the fact that it was only possible to harvest one trial in each case.

TABLE 3

Effect on crop vigour of pre and post emergence applications of pendimethalin and isoproturon

		% Vigour Reduction*							
growth stage at assessment:		tillering				ear emergence			
dose kg a.i./ha pendimethalin		1.3	2.6	2.0	-	1.3	2.6	2.0	-
dose kg a.i./ha isoproturon		1.3	2.6	-	2.5	1.3	2.6	-	2.5
Winter barley	pre em.	5 (3)	-	5 (7)	-	0 (3)	-	0 (7)	-
	post em.	2(14)	6(2)	3 (4)	5 (9)	0(14)	8(2)	0 (4)	1 (9)
Winter wheat	pre em.	6(12)	-	6(13)	2 (3)	2(12)	-	2(13)	0 (3)
	post em.	2(28)	4(9)	0 (3)	2(12)	1(28)	2(9)	0 (4)	1(12)

*Assessed as estimated % visual reduction compared to untreated plots.

( ) indicates number of trials.

(ii) Crop Tolerance

Slight crop vigour reductions resulted from most treatments in winter wheat and winter barley, but in most cases grew out by ear emergence (Table 3). Effects in winter barley were slightly greater than in winter wheat, notably from a double-dose combination of pendimethalin and isoproturon (2.6 + 2.6 kg ai/ha). In general, crops were more sensitive to pre-emergence applications than to those applied post-emergence. Grain yields were not affected by either single or double doses of the combination.

TABLE 4

Effect on grain yield of post emergence applications of pendimethalin and isoproturon (as % of untreated at weed free sites)

pendimethalin (kg a.i./ha):	-	1.3	2.6	
isoproturon (kg a.i./ha):	-	1.3	2.6	S.E.M.
Winter barley	100	102(2)	104(2)	1.46
Winter wheat	100	99(4)	98(4)	3.67

( ) indicates number of trials.

DISCUSSION

A tank mix of 1.3 kg ai/ha pendimethalin and 1.3 kg ai/ha isoproturon was very effective for weed control, and safe in winter wheat and winter barley. Good to excellent control of grass and broad-leaved weeds was achieved, particularly when applications were made pre-emergence. Post emergence applications after the three leaf stage may not be as reliable for control of heavy black-grass infestations.

For control of a wide spectrum of both grass and broad-leaved weeds the combination could be expected to give more consistent results over a wider range of times of application than either of the products used alone at their recommended rates. Where black-grass control is important it is probable that earlier applications, up to the three leaf stage, would be more effective, and control could be further improved by including a higher dose of isoproturon in the combination.

This tank mix combination resulted in significant weed control improvements in winter wheat and winter barley over either herbicide applied alone at standard doses. Control of grass weeds with pendimethalin was improved and broad-leaved weed control and persistence of activity of isoproturon was enhanced. The combination extended the spectrum of weeds controlled and the option exists for either pre- or post-emergence applications, resulting in substantial yield increases, allowing the farmer a greater degree of flexibility in making the applications.

Crop tolerance of this tank mix combination was excellent. No adverse effect on grain yield resulted in either winter wheat or winter barley.

REFERENCES

Holroyd, J. (1968) Control of (*A. fatua*) in Spring Barley with 2-Chloro-3-(4-Chlorophenyl) proprioric acid methyl ester. *Proceedings 9th British Weed Control Conference* *1*, 74.

GRASS AND BROAD-LEAVED WEED CONTROL IN WINTER CEREALS WITH SMY1500

B.J.G. BOLTON, P.W. ROSE, A.P. FISK

Bayer U.K. Limited, Agrochem Division, Eastern Way, Bury St. Edmunds, Suffolk, IP32 7AH, England.

W.G. RICHARDSON

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

ABSTRACT

4-Amino-6-(1,1-dimethylethyl)-3-(ethylthio)-1,2,4-triazin-5(4H)-one, code numbered SMY1500 is a new herbicide for use in winter cereals. Winter wheat, except for four specific cultivars was tolerant of SMY1500. Winter barley though generally more sensitive than winter wheat was not severely damaged. Control of *Alopecurus myosuroides* was best achieved with pre-emergence or autumn post-emergence applications. SMY1500 has given control of *Avena fatua* when applied pre-tillering. *Stellaria media* and *Veronica persica* were well controlled by SMY1500. In pot experiments good activity against *Bromus* spp. was shown. 1.75 kg/ha SMY1500 was required for consistent control of *A. myosuroides* but lower rates controlled broad-leaved weeds.

INTRODUCTION

4-Amino-6-(1,1-dimethylethyl)-3-(ethylthio)-1,2,4-triazin-5(4H)-one, code numbered SMY1500 is a new herbicide discovered by Bayer AG, West Germany. Under extensive testing in Europe and USA SMY1500 has shown promise for the selective control of a range of grass and broad-leaved weeds in winter sown cereals. Chemical, physical and toxicological properties of this herbicide are published in the proceedings of this conference (Hack *et al*, 1985). This paper reports on the biological activity against some major weeds of winter cereals in the U.K., assessed in field trials by Bayer U.K. Limited and in glasshouse experiments by W.R.O. The main objective in three years of testing SMY1500 in the U.K. was the control of *Alopecurus myosuroides* but effects against *Avena fatua*, *Bromus* spp. and broad-leaved weeds were investigated.

MATERIALS AND METHODS

SMY1500 tested in field trials was formulated as a 50% w.p., 60% w.p. or 60% water-dispersible granule. The usual standard in field trials was isoproturon 500 g/litre s.c., but in 1984 trials chlortoluron 500 g/litre s.c. was included. Standards were applied at rates and timings recommended by the manufacturers. In pot experiments metoxuron 500 g/litre s.c. or tri-allate 400 g/litre e.c. were included with isoproturon as standards.

Field experiments

Treatment rates and timings were compared in field trials in the harvest years 1983-85. Trials were sited in commercial crops of winter barley or winter wheat with known infestations of *A. myosuroides*, *A. fatua* or broad-leaved weeds. Where A. myosuroides was the target weed, sites were generally on medium or heavy mineral soils but broad-leaved weed trials were sited on lighter soils.

Applications were made by CO_2-pressurised knapsack sprayer using Tee Jet SS8002 or SS8003 flat fan nozzles at 200-250 kPa and water volumes of 220-300 litres/ha. Weed control trials were of randomised block design with three replicates. Plot size was typically 45m² though initial trials in 1983 used plots of 9m².

Treatment timings were pre-emergence of the crop (in 1984 and 1985 only) early post-emergence in the autumn at GS11-24 (Tottman & Makepeace, 1979) and late post-emergence in the spring at GS24-30.

In cultivar compatibility trials SMY1500 was applied to a range of winter cereal cultivars (Rose et al, 1983). Timings were the same as for the weed control trials. SMY1500 was applied at the highest field rate and at double that rate to establish the margin of crop safety.

Weed control was assessed either by quadrat counts of surviving weeds, usually of 10 x 0.1 m² quadrats per plot or by whole plot scores. On all trials with A. myosuroides present a final quadrat count of heads was made.

Crop tolerance in both weed control and cultivar compatibility trials was assessed by scoring any damage caused. Grain yield from weed control trials was measured by harvesting approximately 27m² from each plot using a Claas Compact 25 combine harvester. Yields were corrected to 14% moisture content.

Glasshouse experiments

In two experiments pre-emergence and post-emergence applications of SMY1500 were tested against a range of grass weeds raised in pots in glasshouses (Richardson & Pollard, 1984). Seeds of A. myosuroides, A. fatua (pre-emergence only), Bromus commutatis, B. hordeaceous, B. sterilis, B. wildenowii, winter barley cv. Igri and winter wheat cv. Avalon were sown. Tri-allate was sprayed onto soil in containers which were then emptied into polythene bags and shaken to incorporate the soil before sowing. Before applying post-emergence treatments plants were thinned to 5 per plot (3 to 4 for A. myosuroides). Post-emergence treatments were applied at GS12-13, except for A. myosuroides which was GS13-21. Treatments were replicated three times and arranged in randomised blocks. Four to five weeks after application treatments were assessed by recording the shoot fresh weights of surviving plants.

RESULTS

Crop tolerance - winter wheat

In cultivar compatibility trials SMY1500 was applied at up to 3.0 kg/ha in 1983-84 and 4.2 kg/ha in 1985. No visible damage was caused to the winter wheat cultivars Armada, Avalon, Avocet, Brigand, Brimstone, Brock, Fenman, Galahad, Hammer, Longbow, Mission, Moulin, Norman and Renard. Aquila, Rapier and Stetson were severely damaged at all rates, in all seasons and at all timings. Virtue was severely damaged at 3 kg/ha in 1983 but not in 1984. The susceptible cultivars suffered plant loss or complete crop kill in extreme cases.

Crop tolerance - winter barley

Pre-emergence application of 4.2 kg/ha SMY1500 caused damage to all nine winter barley cultivars in the cultivar compatibility trial in 1985. At 2.1 kg/ha only Metro and Monix were unaffected. In two weed control trials SMY1500 at rates up to 2.5 kg/ha damaged Igri and Kaskade but Igri, Gerbel and Panda were undamaged in other trials.

Autumn post-emergence treatments up to 2.1 kg/ha in 1984 and 1985 caused no visible damage to any cultivars except for a slight effect against Tipper. 4.2 kg/ha in 1985 was damaging to all cultivars, and 3.0 kg/ha in 1984 affected Tipper, Panda and Igri. In two weed control trials in 1984 Igri and Maris Otter were slightly damaged by 1.75 kg/ha but in two other trials Igri and Marko were unaffected. In 1985 weed control trials no crops were affected at this timing.

Spring post-emergence treatments of up to 2.1 kg/ha in 1983-85 caused no visible damage in cultivar compatibility or weed control trials. The cultivars Fenella, Marko, Metro, Sonja and Tipper were damaged by 3.0 kg/ha SMY1500 in 1984. Halcyon, Maris Otter and Tipper were affected by 4.2 kg/ha in 1985.

Crop damage to winter barley cultivars was rarely severe, mainly occurring as leaf chlorosis, slight necrosis or at worst thinning of the crop.

Control of *A. myosuroides* (Table 1)

Pre-emergence applications of 1.4-2.1 kg/ha SMY1500 gave excellent control of *A. myosuroides*, particularly at the higher rates.

Results from 1984 autumn post-emergence application of 1.75 kg/ha show control of *A. myosuroides* at a level similar to isproturon, but at lower rates SMY1500 was inferior. In 1983 and 1985 lower rates (1.2-1.5 kg/ha) gave excellent control of *A. myosuroides*.

Post-emergence applications in the spring gave variable control. In two trials in 1983 very effective control was given by SMY1500. In 1984 spring treatments were inconsistent but in 1985 spring applied SMY1500 generally gave excellent control of *A. myosuroides*.

Table 2 shows results from a single trial at Peldon, Essex in 1984 where unusually, isoproturon and chlortoluron were significantly less effective than the higher rates of SMY1500 in controlling *A. myosuroides*.

Control of other grass weed species

Information on *A. fatua* control is limited. Pre-emergence and autumn post-emergence treatments were similarly effective with SMY1500 at the highest rates broadly equivalent to isoproturon. Spring post-emergence applications gave very variable and often inadequate control.

Poa annua was well controlled by pre-emergence and post-emergence applications of 1.25 kg/ha SMY1500.

TABLE 1. Median % reduction in numbers of A. myosuroides heads (Range given beneath median figure).

Timing:	Pre-em.		Post-em.(Autumn)			Post-em.(Spring)		
Year:	1984	1985	1983	1984	1985	1983	1984	1985
Weed GS:	-	-	11-22	11-23	11-22	25-28	12-30	21-29
Dose kg/ha								
SMY1500								
1.2-1.25	-	-	98 95-100	83 23-100	-	-	50 0-98	-
1.4-1.5	98	96 82-100	-	89 63-100	97 80-100	97 95-99	75 0-100	94 54-100
1.75-1.8	-	98 94-100	-	95 63-100	96 91-100	100 99-100	85 0-100	99 66-100
2.1	-	99 95-100	-	-	98 93-100	-	-	99 75-100
Isoproturon								
2.1	-	-	-	-	-	-	83 0-100	98 56-100
2.5	-	97 85-100	-	97 68-100	94 73-100	-	-	-
No. trials:	1	8	2	13	9	2	13	9

Median range population A. myosuroides (heads/m^2):
1983: 213, (27-399); 1984: 531, (98-1872); 1985: 203, (161-1923).

TABLE 2. Reduction of A. myosuroides in a trial at Peldon, Essex in 1984.

Timing:		Post-emergence (Autumn)		Post-emergence (Spring)	
Weed GS:		12		21-25	
	Dose kg/ha	no. heads/m^2	% reduction	no. heads/m^2	% reduction
1. Control		590.0	0	616.3	0
2. SMY1500	1.25	179.7	70	307.0	50
3. SMY1500	1.5	69.9	88	101.0	84
4. SMY1500	1.75	26.0	96	91.0	85
5. Chlortoluron	2.75	-	-	526.0	15
	3.5	342.0	42	-	-
6. Isoproturon	2.1	-	-	390.0	37
	2.5	190.7	68	-	-
LSD 5%		86.6		98.7	

Broad-leaved weed control

Control figures for weed species which occurred in sufficient numbers in two or more trials are given in Table 3. Stellaria media and Veronica persica were sensitive to SMY1500 at all application timings but other weeds were more effectively controlled by later timed treatments.

TABLE 3. Median (range) % reduction in individual broad-leaved weed species.

Weed Species	GS at application	SMY1500 Dose kg/ha 1.2-1.25 Median		No. sites	SMY1500 Dose kg/ha 1.75-1.8 Median		No. sites
Matricaria	pre-em.	21	(17-25)	2	-		-
perforata	coty-1 lf.	95	(83-100)	3	100		1
Myosotis	pre-em.	66	(32-100)	2			
arvensis	coty	72	-	1			
	3-6 lf.	99	(97-100)	2	99	(97-100)	2
Stellaria	pre-em.	91	(62-100)	6	100		1
media	coty-4 lf.	100	(94-100)	6	100	(100-100)	2
	6lf.-15cm diam.	100	(100-100)	4	100	(100-100)	2
Veronica	pre-em.	97	(74-100)	5	98	(67-100)	10
persica	coty-4 lf.	-		-	100	(95-100)	6
Viola	pre-em.	3	(0-80)	4	-		-
arvensis	coty-2 lf.	80	(0-100)	3	-		-

Information on weed species occurring in single trials suggests Aphanes arvensis is susceptible to 1.2-1.25 kg/ha SMY1500 applied pre-emergence and post-emergence; Galium aparine is not controlled by SMY1500; Lamium purpureum may be susceptible to autumn post-emergence and V. hederifolia to spring post-emergence treatments.

Yield results

Winter wheat trials showed yield benefits consistent with the levels of A. myosuroides control achieved. Lower tolerance of SMY1500 by winter barley may have affected the yield results. The yield response from 1.75 kg/ha SMY1500 was less than from 1.5 kg/ha SMY1500 in 10 of 18 comparisons on winter barley. The median yield difference between 1.75 kg/ha and 1.5 kg/ha was -1%, with a range of -11% to +7%. None of these differences were significant.

Pot experiments

Table 4 shows the fresh weight reductions of weed species and cereals due to various herbicides. A reduction of 70% or more is regarded as control of that species.

Table 4. Response of A. myosuroides, A. fatua, Bromus spp., wheat and barley to various herbicides applied post-emergence and pre-emergence, shown as % shoot fresh weight relative to untreated control.

Dose kg/ha		A. myosuroides	A. fatua	B. commutatis	B. hordeaceous	B. sterilis	B. wildenowii	Barley 'Igri'	Wheat 'Avalon'
(a) Pre-emergence									
Control (mean shoot fresh wt. g/pot)		100 (1.13)	100 (4.24)	100 (2.26)	100 (3.02)	100 (3.72)	100 (2.50)	100 (11.30)	100 (9.16)
SMY1500	0.5	<1	38	18	22	44	70	96	103
	1.0	0	3	<1	<1	15	26	95	87
	1.5	<1	<1	<1	0	2	7	50	69
	2.0	<1	1	0	0	1	7	24	57
Isoproturon	0.375	<1	73	108	82	28	125	101	100
	0.75	<1	32	72	72	47	95	91	87
Tri-allate	1.0	20	1	83	62	<1	88	110	95
	2.0	24	2	13	22	0	81	106	86
	S.E.	10	8	8	8	8	7	5	3
(b) Post-emergence									
Control (mean shoot fresh wt. g/pot)		100 (5.39)	-	100 (6.75)	100 (8.46)	100 (10.46)	100 (9.71)	100 (12.25)	100 (10.13)
SMY1500	0.15	9		33	57	79	80	101	100
	0.3	5		15	22	36	40	105	100
	0.6	2		4	3	17	15	99	94
	1.2	1		2	<1	4	4	94	84
Isoproturon	0.75	2		25	76	15	47	103	94
	1.5	2		5	14	14	23	83	37
Metoxuron	0.75	2		68	86	89	94	103	96
	1.50	1		15	44	29	99	91	98
	S.E.	8		7	7	7	7	2	3

Pre-emergence application of SMY1500 at 1.0 kg/ha controlled all weed species but was not sufficiently selective at this rate with wheat appearing sensitive. At 0.5 kg/ha wheat was undamaged but A. fatua, B. sterilis and B. wildenowii were not controlled. Isoproturon at 0.75 kg/ha controlled only A. myosuroides and also damaged wheat and barley. Tri-allate at 2 kg/ha controlled all weeds except for B. wildenowii, but also affected wheat. Though safer at 1 kg/ha tri-allate also failed to control B. commutatis or B. hordeaceous.

Post-emergence treatments with SMY1500 controlled A. myosuroides at 0.15 kg/ha; B. commutatis and B. hordeaceous were controlled at 0.3 kg/ha and the remaining Bromus spp. were controlled at 0.6 kg/ha. Barley and wheat were unaffected at all but the 1.2 kg/ha rate. Isoproturon at 0.75 kg/ha controlled all weeds except B. hordeaceous and B. wildenowii and though 1.5 kg/ha improved control to include these species it also significantly affected wheat and barley. Metoxuron was safe to wheat at 1.5 kg/ha but did not control B. hordeaceous and B. wildenowii.

DISCUSSION

SMY1500 showed excellent selectivity in wheat at all timings, except for Aquila, Rapier and Stetson which were clearly susceptible cultivars and Virtue which was suspect.

Winter barley cultivars were more sensitive to SMY1500 particularly from pre-emergence and autumn post-emergence treatments. Post-emergence treatments in the spring were generally safer. Damage to winter barley was rarely severe even at the highest rates of SMY1500. There is an indication that yields may have been slightly reduced by SMY1500 at the highest rates of use but this is tolerable compared with the adverse effects of poorly controlled A. myosuroides.

The results indicate a need for a minimum dose of 1.75 kg/ha SMY1500 to achieve reliable control of A. myosuroides, although 1.5 kg/ha was only marginally less effective in 1983 and 1985. The most consistent control was achieved with pre-emergence or early post-emergence treatments. Though less reliable spring application may still be of practical use where more timely applications have been impossible.

Control of A. fatua with SMY1500 was variable, due in part to the variations in the time of emergence of the weed. Control appeared to be better with treatments applied before tillering, but pre-emergence applications were unreliable probably because of chemical being leached from the soil. Leaching of SMY1500 has already been recognised as a problem of sandy soils (Hack et al, 1985).

The short persistence of SMY1500 on light soils was shown by the broad-leaved weed control results. Though initially effective, pre-emergence and autumn post-emergence treatments did not give control throughout the season. The broadest spectrum of control was given by spring post-emergence treatments. SMY1500 gave very good control of the common autumn germinating weeds S. media and V. persica. If used alone it is unlikely to be sufficiently effective in controlling other autumn germinating weeds such as Viola arvensis and G. aparine.

A result of particular interest came from a single trial at Peldon, Essex in 1984. In all other trials in 1984 isoproturon gave very good control of A. myosuroides yet at Peldon it proved to be much less effective. SMY1500 at 1.5 kg/ha and 1.75 kg/ha gave significantly better control of A. myosuroides than isoproturon or chlortoluron. Subsequent information may explain this result. It was reported (Moss & Cussans, 1985) that A. myosuroides, sampled from a field in the same locality which had received intensive herbicide treatment with isoproturon or chlortoluron, showed a high degree of resistance to chlortoluron. It was discovered that our own trial at Peldon was sited in a field which had received 20 applications of isoproturon or chlortoluron since 1971, with 12 since 1979. It seems possible that A. myosuroides in our trial had become more tolerant of substituted urea herbicides yet was well controlled by SMY1500.

The pot experiments showed that SMY1500 has excellent activity against B. sterilis and other Bromus spp. This work will be continued with trials to determine activity, rates and timings under field conditions. Although at an early stage SMY1500 appears to be a promising herbicide against a weed for which only limited chemical control is currently available.

ACKNOWLEDGEMENT

The authors would particularly like to thank T.M. West who conducted the pot experiments and also the farmers who provided assistance with field trials. The help of colleagues within Bayer U.K. Limited and W.R.O. was also much appreciated.

REFERENCES

Hack, H.; Eue, L.; Strang, R.H.; Zeck, W.M. (1985) SMY1500 - A new selective herbicide for weed control in winter cereals. Proceedings 1985 British Crop Protection Conference - Weeds.

Moss,S.R.; Cussans, G.W. (1985) Variability in the susceptibility of Alopecurus myosuroides (black-grass) to chlortoluron and isoproturon. Aspect of Applied Biology 9, The biology and control of weeds in cereals, 91-98.

Richardson, W.G.; Pollard, F. (1984) The response of different cultivars of wheat, barley, Bromus sterilis and B. pectinatus to metribuzin applied pre-emergence. Tests of Agrochemicals and Cultivars No. 5 (Annals of Applied Biology 104, Supplement), 70-71.

Rose, P.W.; Rowley, N.K.; Morris, D.B. (1983) An approach to the field evaluation of crop tolerance to herbicides. Aspects of Applied Biology 3, Crop sensitivity to herbicides, 25-34.

Tottman, D.R.; Makepeace, R.J. (1979) An explanation of the decimal code for the growth stages of cereals, with illustrations. Annals of Applied Biology 93, 221-234.

Wilson, B.J.; Thornton, M.E.; Lutman, P.J.W. (1985) Yields of winter cereals in relation to the timing of control of black-grass (Alopecurus myosuroides Huds.) and broad-leaved weeds. Aspects of Applied Biology 9, The biology and control of weeds in cereals, 41-48.

AC 222,293 FOR THE CONTROL OF GRASS WEEDS IN WINTER CEREALS IN THE UK: FIELD STUDIES OF EFFICACY AND CROP TOLERANCE

A. A. HUDSON, S. C. E. TOWNSEND

Cyanamid of Great Britain Limited, Fareham Road, Gosport, Hampshire, UK

ABSTRACT

This paper summarises the results of field trials conducted with AC 222,293 on commercial winter cereal crops in the UK between 1979 and 1985. Results on the efficacy of applications of AC 222,293 at doses of 0.5 - 1.0 kg a.i./ha have demonstrated good to excellent control of *Avena* spp. and some other grass species. Control or suppression of *Alopecurus myosuroides* and a limited range of broad-leaved weed species was also obtained. Crop safety data, assessed as crop vigour during growth, and grain yield in approximately 30 trials have demonstrated that AC 222,293 at rates envisaged for commercial usage, can be safely used post-emergence in winter wheat and winter barley.

INTRODUCTION

AC 222,293 (a mixture of methyl 6-(4-isopropyl-4- methyl-5-oxo-2-imidazolin-2-yl)-*m*-toluate and the methyl 2-(4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl)-*p*-toluate isomer) proposed common name imazamethabenz, is a new post-emergence herbicide for control of grass weeds in cereals discovered by the American Cyanamid Company. Results of field studies have been reported from various countries (Kirkland and Shafer 1982, Van Hoogstraten 1983 and 1984, Efthimidis and Skorda 1985). The product is being developed in many countries under the trademark 'Assert*' herbicide. Results of tolerance and weed spectrum studies in the glass house were reported by Richardson, *et al*. (1982) for pre-emergence applications and by Richardson *et al*. (1981) and Shaner *et al*. (1982), for post-emergence applications. Roberts and Bond (1982) also reported the weed spectrum in studies of drilled vegetable crops.

AC 222,293 is particularly effective against *Avena fatua*, *A.ludoviciana*, and *Alopecurus myosuroides*. Pilmoor and Caseley (1984) demonstrated foliar and root uptake of AC 222,293 in both *Avena* spp. and *Alopecurus myosuroides*. Under controlled environmental conditions they investigated the stages at which the weed species are most susceptible following applications at doses below those recommended for field applications. Results of efficacy and crop safety when AC 222,293 was applied at the recommended doses in field trials in Europe were reported by Van Hoogstraten (1983).

* Trademark of American Cyanamid Company

The purpose of this paper is to summarise the results of trials conducted on commercial winter cereal crops in the UK between 1979 and 1985. These results include data from 106 trials on the efficacy of AC 222,293 against the major weeds, Avena spp. and Alopecurus myosuroides, in winter wheat and winter barley.

In addition, 30 crop safety trials were conducted in weed-free commercial crops.

MATERIALS AND METHODS

AC 222,293 was used in various formulations, including wettable powders, emulsifiable concentrates, and suspension concentrates. No differences in efficacy or crop safety were observed between formulations; therefore this paper includes results obtained using all formulations.

Data presented were obtained from replicated small-plot trials of randomised block design with three or four replicates. Plot sizes were 2 x 8 m for efficacy trials and 2 x 12 m or 3 x 15 m for weed-free crop tolerance trials. All treatments were applied using CO_2 pressurised knapsack sprayers fitted with fan nozzles spraying 200 l/ha at a pressure of 280 kPa.

In efficacy trials AC 222,293 was applied at different doses and times of application. The doses ranged from 0.5 to 1.0 kg a.i./ha applied at different times pre- or post-emergence to the crop and weeds. Grass weed control was assessed by quadrat counts when the flowering head had emerged. Control of A. myosuroides was calculated as reduction of heads in comparison to untreated plots. Avena spp. control was assessed by counting panicles in categories according to size, as described by Holroyd (1968). Control was calculated as reduction of spikelets in comparison to untreated plots. Broad-leaved weeds were assessed by plant counts using quadrats and again control was calculated as reduction of plants compared to untreated plots.

Trials on crop tolerance tested AC 222,293 at doses ranging from 0.5 to 2.0 kg a.i./ha applied post-emergence to the crop. Doses of up to 2.0 kg a.i./ha were used to determine crop safety at doses well above possible field levels. For these trials, commercial winter cereal plots were selected where significant weed infestations were either absent or had been previously controlled. Visual estimates of effects on crop vigour were made and plots were harvested using trial-plot combine harvesters to determine grain yields.

RESULTS

Efficacy

Wild-oat Control

Mean data on control of Avena spp. from six years (1979-1985) are presented in Table 1. The results are presented according to wild oat growth stage at the time of application, using the scale determined by Tottman and Makepeace (1979). Values are given for a range of doses applied prior to weed emergence and at six growth stages after weed emergence. It should be noted in making comparisons between treatments that the mean data presented are compiled from different numbers of trials and this will affect the validity of some comparisons.

Table 1 demonstrates that AC 222,293 applied at 0.6 kg a.i./ha or above is effective over a wide range of Avena spp. growth stages, from one leaf (GS 10-11) to mid-tillering. Pre-emergence applications were generally much less effective than post-emergence applications up to mid-tillering. The most consistent control followed applications between GS 10-14 and declined substantially after mid-tillering (GS 23+), except at the highest dose of 1.0 kg a.i./ha.

AC 222,293 applied early post-emergence (GS 10-14) at 1.0 kg a.i./ha was more effective than chlortoluron, isoproturon or diclofop-methyl, the latter applied at 0.57 kg a.i./ha. From the beginning of tillering (GS 21 onwards) this dose was comparable to diclofop-methyl (1.1 kg a.i./ha) and difenzoquat.

Blackgrass Control

AC 222,293 was active on A. myosuroides when applied either pre- or post-emergence (Table 2). Control of blackgrass with pre-emergence applications was variable. Post-emergence applications were generally more effective. Most consistent control followed applications between GS 12 and GS 23 of the weed, with up to 89% control at doses of 0.75-0.8 kg a.i./ha. Applications made after GS 24 were usually less effective.

Control of other grass weeds

AC 222,293 also showed good activity against Arrhenatherum elatius var. bulbosum (onion couch) and Apera spica-venti (loose silky bent). From limited trial data (7 sites) control of A. elatius ranged from 75-100 percent at doses of 0.625-1.0 kg a.i./ha. There are no records to confirm whether these infestations arose from bulbils or seed. Control of A. spica-venti (mean 87 percent) was recorded at four sites from doses of 0.5-0.75 kg a.i./ha. In five unreplicated trials 95-100 percent control of Poa trivialis was recorded at doses of 0.5-0.625 kg a.i./ha AC 222,293.

TABLE 1

Mean percent control of Avena spp. by application of different doses of AC 222,293 at different weed growth stages from pre-emergence to first node detectable.

Treatment	Dose (kg a.i./ha)	Control of Avena spp. (%) and growth stage at application PRE	GS10-11	GS12-14	GS21-23	GS23+	GS30-31
AC 222,293	0.5	75 (8)	88 (6)	81(14)	78(23)	72(16)	60 (2)
AC 222,293	0.6-0.65	71(10)	92(15)	90(23)	87(16)	75(13)	65 (6)
AC 222,293	0.75-0.8	82 (8)	95(11)	93(23)	91(25)	76(21)	69 (7)
AC 222,293	1.0	85 (9)	98 (9)	98 (9)	98 (5)	97 (5)	88 (4)
chlortoluron	3.5	64 (4)	80 (9)	77 (6)	-	-	-
isoproturon	2.5	57 (1)	86 (5)	88 (4)	72 (4)	77 (2)	-
diclofop-methyl	0.57	-	100 (1)	81 (4)	74(10)	91 (2)	-
diclofop-methyl	1.1	-	-	-	95 (2)	99 (1)	-
l-flamprop-isopropyl 0.6	-	-	-	74 (3)	77 (1)	91 (2)	
difenzoquat	1.0	-	-	94(10)	96 (3)	96(11)	90(11)

Numbers in parentheses indicate the number of trials from which each mean is calculated.

TABLE 2

Mean percent control of A. myosuroides by applications of different doses of AC 222,293 at different weed growth stages from pre-emergence to first node detectable.

Treatment	Dose (kg a.i./ha)	Control of A. myosuroides (%) and growth stage at application PRE	GS10-11	GS12-14	GS21-23	GS23+	GS30-31
AC 222,293	0.5	80 (1)	56 (1)	82 (7)	80(10)	69(14)	63 (1)
AC 222,293	0.6-0.65	49 (3)	73(21)	78(20)	74(18)	81(35)	67 (4)
AC 222,293	0.75-0.8	71 (4)	75(15)	83(21)	89(18)	79(39)	72 (5)
AC 222,293	1.0	34 (1)	85(20)	89 (8)	82(19)	73(27)	79(14)
chlortoluron	3.5	85 (3)	85 (5)	96 (6)	94 (1)	-	-
isoproturon	2.5	-	-	61 (8)	-	98 (4)	-
diclofop-methyl	0.57	-	-	94 (2)	83 (7)	-	-

Numbers in parentheses indicate the number of trials from which each mean is calculated.

Broad-leaved weed control

Table 3 summarises the control of broad-leaved weeds with AC 222,293 and classifies the species observed in UK field trials into susceptible (S), moderately susceptible (MS), moderately resistant (MR) and resistant (R). Data on control of broad-leaved weeds are means from applications made pre-emergence to late post-emergence. Doses of AC 222,293 were between 0.625 and 1.0 kg a.i./ha.

TABLE 3

Susceptibility, as defined by mean percent control, of broad-leaved weed species to application of AC 222,293 in UK field trials.

Susceptibility rating	Weed species	Mean % control	(No. Trials)
Susceptible (S)	Sinapis arvensis	87	12
Moderately susceptible (MS)	Myosotis arvensis	64	12
Moderately resistant (MR)	Galium aparine	52	106
	Polygonum spp.	35	14
	Veronica spp.	32	106
Resistant (R)	Lamium purpureum	24	12
	Viola arvensis	22	80
	Papaver rhoeas	20	26
	Stellaria media	16	15
	Aphanes arvensis	7	24
	Matricaria spp.	1	21

S $\geqslant$85% control; MS $\geqslant$ 60%, < 85% control
MR $\geqslant$30%, <60% control
R < 30% control.

Crop Safety (Weed-free Crops)

Winter wheat

Small effects on crop vigour were observed as slight reductions in height following doses up to 0.8 kg a.i./ha. At doses of 1.0 to 2.0 kg a.i./ha AC 222,293 vigour reductions were slightly greater. There were no effects on grain yield at any dose.

Winter barley

Doses of 0.5-0.8 kg a.i./ha AC 222,293 caused small reductions of crop vigour. Higher doses caused apparently greater effects on vigour but grain yields were not affected significantly.

Screening of large numbers of available varieties of winter wheat and winter barley over four years has not indicated sensitivity in any varieties.

DISCUSSION

AC 222,293 has shown effective control of five grass weeds: *Avena* spp., *A. myosuroides*, *Arrhenatherum elatius* var. *bulbosum*, *Apera spica-venti* and *Poa trivialis*.

AC 222,293 doses of 0.6 to 1.0 kg a.i./ha, applied before early tillering gave control of *Avena* spp. equal or superior to the standard products used with an excellent margin of safety to all winter wheat and winter barley varieties tested.

None of the trials described had subsequent applications in spring for control of wild oats, demonstrating effective residual activity after autumn application of AC 222,293. This may explain the greater efficacy of AC 222,293 on wild oats in comparison to chlortoluron and isoproturon. The herbicidal activity of AC 222,293 is by both foliar and root uptake (Shaner *et al*., (1982). This, combined with good persistence in the soil is a valuable atribute under UK conditions where wild oat germination in autumn cereals is usually prolonged and erratic.

REFERENCES

Efthimidis, P. and Skorda E.A. (1985) The efficacy of AC 222,293 applied post-emergence at various growth stages and rates against wild-oats and other weeds in cereals under Greek conditions. *Med. Fac. Landbouww Rijks Univ Gent*, *50/2A* 257-264.

Holroyd, J. (1968) The control of *Avena fatua* in Spring Barley with 2-Chloro-3-(4-Chlorophenyl) propionic acid methyl ester. *Proceedings 9th British Weed Control Conference* *1*, 74

Kirkland, K.; Shafer, N.E. (1982) AC 222,293 A new post emergent herbicide for cereals: field studies. *Proceedings 16th British Crop protection Conference - Weeds* *1*, 33-38.

Pilmoor, J.B. and Caseley, J.C. (1984) The influence of growth stage and foliage or soil application on the activity of AC 222,293 against *Alopecurus myosuroides* and *Avena fatua*. *Annals of Applied Biology* *105*, 517-527.

Richardson, W.G.; West, T.M. and Parker, C. (1981) The activity and post emergence selectivity of some recently developed herbicides SSH-L11, MB 30755, AC 213087, AC 222,293 and DOWCO 433. *Weed Research Organisation* Technical Report, *No. 63*, 1981.

Richardson, W.G.; West, T.M. and Parker, C. (1982) The activity and pre emergence selectivity of some recently developed herbicides AC 213087 and AC 222,293. *Weed Research Organisation* Technical Report, *No. 66*, 1982.

Roberts, H.A. and Bond, W. (1982) Evaluation of AC 222,293 for weed control in drilled vegetable crops. *Tests of Agrochemicals and Cultivars* (*Annals of Applied Biology* *102*, Supplement), No 4, 112-113.

Shaner, D.L.; Umeda, K.; Ciarlante, D.R. and Los, M. (1982) AC 222,293 A new post-emergent herbicide for cereals, greenhouse studies. Proceedings 16th British Crop Protection Conference - Weeds 1, 25-31.
Tottman, D. R. and Makepeace, R. J. (1979) An explanation of the decimal code of growth stages of cereals, with illustrations. Annals of Applied Biology 93, 221-234.
Van Hoogstraten, S.D. (1983) Field performance of AC 222,293 in Europe during 1982. Proceedings 10th International Congress of Plant Protection 2, 583.
Van Hoogstraten, S.D. (1984) AC 222,293 - A new cereal herbicide for post-emergence control in grass weeds 1982/83 Field Trials Agrichem '84 Bratislava CSSR Paper C - 23.

THE USE OF METSULFURON-METHYL ALONE AND IN MIXTURE WITH CHLORSULFURON FOR WEED CONTROL IN CEREALS IN THE UNITED KINGDOM

A.P. SELLEY, P.J. HANEY, J.R. AUSTIN

Du Pont UK Limited, Agricultural Chemicals Department, Wedgwood Way, Stevenage, Herts. SG1 4QN

ABSTRACT

The development of two herbicides introduced recently into the UK market is described. Chlorsulfuron plus metsulfuron-methyl applied in the autumn to winter cereals, controls a wide spectrum of broad leaved weeds including *Veronica persica*, *Galium aparine*, *Stellaria media*, and *Veronica hederifolia*. The product has useful grass activity which in mixture or sequence with other grass herbicides results in additive control of key grass weeds including *Alopecurus myosuroides* and *Poa annua*. The highly active metsulfuron-methyl applied as a spring herbicide is effective against a broad spectrum of broad leaf weeds including *Matricaria spp*, *Viola arvensis* and *S. media* on both winter and spring cereals. Tank mix options with mecoprop or ioxynil plus bromoxynil are discussed.

INTRODUCTION

The sulfonylurea herbicide chlorsulfuron was introduced in 1980 by Palm et al and was followed by metsulfuron-methyl in 1983 (Doig 1983). Since then, a number of papers have reported on the use of these products in the UK. (Upstone et al 1982, Swinchatt 1982, Swann 1982, Swann 1984). This paper reviews the development of a new autumn herbicide for winter cereals containing chlorsulfuron and metsulfuron-methyl first introduced into the UK market in 1984 under the trade name 'FINESSE' and also a broad spectrum spring herbicide containing metsulfuron-methyl trade named 'ALLY'.

MATERIALS AND METHODS

Herbicidal activity for two different products was evaluated, chlorsulfuron plus metsulfuron-methyl for autumn use and metsulfuron-methyl alone or in tank mixtures as a spring herbicide.

All trial plots were sprayed using a modified hand-held Oxford Precision Sprayer operating at 200 kPa. pressure. Herbicides were applied in 200 l/ha using Teejet 8002 nozzles. Plots for weed control evaluations were generally 8 m x 2 m, replicated three times in randomised blocks and were not taken to yield. Broad leaved weed assessments were made in May - June by visual assessment of weed growth compared with untreated control plots. Grass weed assessments were made at heading using the same technique.

Crop tolerance trials were on sites with few weeds and were generally 12 - 15 m x 2 - 3 m, replicated four times in randomised blocks and harvested with a mini-combine.

Autumn tests between 1983 and 1984 evaluated the efficacy of chlorsulfuron plus metsulfuron-methyl (20% water dispersible granule) for grass and broad leaf weed control in winter wheat and barley. Herbicides used in the grass weed tests included triallate (10% granule), isoproturon (500 g/litre s.c.), chlortoluron (500 g/litre s.c.), diclofop-methyl (380 g/litre e.c.) and trifluralin (480 g/litre e.c.). In the broad leaf weed trials, the performance of chlorsulfuron plus metsulfuron-methyl was compared with trifluralin plus linuron (360 g/litre E.C.) and methabenzthiazuron (70% w.p.).

Results represent the % control observed following application pre or early post-emergence in winter wheat and post-emergence on winter barley.

Spring herbicide treatments of metsulfuron-methyl alone or in tank mixture with mecoprop (570 g/litre) or ioxynil plus bromoxynil (400 g/litre) were applied between GS 13 and 30. (Tottman et al (1979)) Broad leaved weed control in winter cereals was compared with mecoprop plus ioxynil plus bromoxynil (560 g/litre). In spring cereals, the standards dicamba plus mecoprop plus MCPA (354 g/litre), mecoprop and chlorsulfuron plus ioxynil plus bromoxynil (5 + 250 g ai/ha) were used.

RESULTS

Autumn application of chlorsulfuron plus metsulfuron-methyl

Results for the broad leaf weed trials are presented in Table 1. These indicate the high levels of control achieved with chlorsulfuron plus metsulfuron-methyl following application either pre or early post emergence on important weeds including V.arvensis, Matricaria spp, S.media, V.persica and V.hederifolia together with useful activity on G.aparine. Susceptible weeds exhibited a die back of the growing points, general yellowing followed by tissue necrosis and death. Any remaining weeds were severely stunted and did not compete with the crop.

Results for the control of Poa annua are presented in Table 2. Pre-emergence application of chlorsulfuron plus metsulfuron-methyl gave a useful suppression of P. annua with control falling off at the post-emergence timing. Significant additive control was observed using a tank mixture with trifluralin making it the best pre-emergence treatment. Tank mixtures of reduced rates of chlortoluron or isoproturon with chlorsulfuron plus metsulfuron-methyl resulted in comparable control to isoproturon 1500 g ai/ha and chlortoluron 2750 g ai/ha.

TABLE 1

% Control of broad leaved weeds in winter cereals 1983-84, application pre or early post emergence of the crop.

Treatment + application timing	Rate g ai/ha	Viola arvensis	Matricaria spp	Stellaria media	Veronica persica	Veronica hederifolia	Galium aparine
pre-emergence chlorsulfuron + metsulfuron-methyl	15 + 5	85	91	96	96	93	77
pre-emergence trifluralin + linuron	1440 - 1800	62	82	98	96	54	23
No. of sites		4	7	8	6	3	2
post-emergence chlorsulfuron + metsulfuron-methyl	15 + 5	89	92	98	97	92	72
post-emergence methabenzthiazuron	1575	73	74	87	96	33	13
No. of sites		3	8	9	6	3	3

TABLE 2

Percentage control of P. annua plants 1984-85 in winter cereals

Treatment	Rate (g ai/ha)	Pre-em	Post-em
1. chlorsulfuron + metsulfuron-methyl	15 + 5	62	24
2. chlorsulfuron + metsulfuron-methyl + chlortoluron	15 + 5 + 2050	93	91
3. chlorsulfuron + metsulfuron-methyl + isoproturon	15 + 5 + 1125	86	91
4. chlorsulfuron + metsulfuron-methyl + trifluralin	15 + 5 + 960	95	
5. chlortoluron	2750	92	95
6. isoproturon	1500	86	93
7. trifluralin	960	72	
No. of sites		7	7

Trial results presented in Table 3 indicate that chlorsulfuron plus metsulfuron-methyl has a useful level of activity on A. myosuroides with marginally superior control pre-emergence. Tank mixing chlorsulfuron plus metsulfuron-methyl with either chlortoluron or isoproturon gave additive control compared with either of these standards alone. A sequential application of triallate or diclofop-methyl with chlorsulfuron plus metsulfuron-methyl gave generally superior control to the standards, especially when the chlorsulfuron plus metsulfuron-methyl was applied pre-emergence.

TABLE 3

Percentage control of flowering heads of A.myosuroides 1984-85 in winter cereals

Treatment	Rate (g ai/ha)	Pre-em	Post-em
1. chlorsulfuron + metsulfuron-methyl	15 + 5	82	79
2. chlorsulfuron + metsulfuron-methyl + chlortoluron	15 + 5 + 3500	94	94
3. chlorsulfuron + metsulfuron-methyl + isoproturon	15 + 5 + 2500	93	95
4. chlortoluron	3500	86	86
5. isoproturon	2500	90	91
6. triallate + chlorsulfuron + metsulfuron-methyl	2250 + 15 + 5	92	**88
7. chlorsulfuron + metsulfuron-methyl + diclofop-methyl	15 + 5 + 570	*93	89
No. of sites		9	19

** Triallate applied pre-em. * Diclofop-methyl applied post-emergence

Yield results presented in Table 4 indicate that chlorsulfuron plus metsulfuron-methyl has a wide margin of crop safety at single and double commercial use rates.

Spring application of metsulfuron-methyl

Broad leaf weed control results for six key species following application to both winter wheat and barley are presented in Table 5. These results demonstrate the high level of activity of metsulfuron-methyl on S. media, V.persica, Matricaria spp and P.rhoeas with control comparable to the standard mecoprop plus ioxynil plus bromoxynil. Activity on V.arvensis, which were at the young plant stage (4 - 8 cm) at time of application is superior to the standards. Metsulfuron-methyl has little activity on V. hederifolia once it is beyond the cotyledon stage. Tank mixtures with either mecoprop or ioxynil plus bromoxynil increased control of this weed to the susceptible category.

TABLE 4

Yield relative to untreated plots treated in the autumn of 1983 on winter wheat or winter barley

Treatment	Rate (g ai/ha)	Winter wheat pre-em	Winter wheat post-em	Winter barley post-em
1. chlorsulfuron + metsulfuron-methyl	15 + 5	107	105	102
2. chlorsulfuron + metsulfuron-methyl	30 + 10	105	106	106
No. of sites		7	7	4

TABLE 5

% Control of broad leaf weeds in winter cereals 1983 and 1984.

Treatment	Rate g ai/ha	Stellaria media	Veronica persica	Veronica hederifolia	Matricaria spp	Viola arvensis	Papaver rhoeas
metsulfuron-methyl	6	99	94	28	99	71	99
metsulfuron-methyl + mecoprop	6 + 2850	100	96	85	99	67	99
metsulfuron-methyl + ioxynil + bromoxynil	6 + 200 + 200	97	97	88	99	77	99
mecoprop + ioxynil + bromoxynil	2529 - 2800	92	99	93	95	52	90
No. of sites		14	9	5	8	8	6

Trial results and extensive commercial useage on a wide range of soil types has indicated that metsulfuron-methyl alone or in mixture with chlorsulfuron has a wide margin of crop safety on both winter and spring cereals. This combined with the broad spectrum herbicidal activity offers the farmer a useful advance in cereal weed control.

ACKNOWLEDGEMENTS

Thanks are due to the many farmers who have provided trial sites and co-operated with this work, and also to colleagues at Du Pont.

REFERENCES

Doig, R.; Carraro, G.A.; McKinley, N.D.; DPX T6376 - a new broad spectrum cereal herbicide. Proceedings of the 10th International Congress of Plant Protection 1983, 324-331

Palm, H.L.; Riggleman, J.D.; Allinson, D.A.; (1980). Worldwide review of the Cereal Herbicide - DPX 4189. Proceedings 1980 British Crop Protection Conference - Weeds 1, 1-6.

Swann, N.B. (1982). Autumn application of Chlorsulfuron for the Control of broad-leaved weeds. Aspects of Applied Biology 1, Broad-leaved weeds and their Control in cereals 77-85.

Swann, N.B. (1984). Two new herbicides for use in Spring Barley in Northern Britain. Proceedings Crop Protection in Northern Britain 1984.

Swinchatt, M.L. (1982). The use of chlorsulfuron for the control of weeds in spring barley. Aspects of Applied Biology 1, Broad-leaved weeds and their control in cereals, 117-126

Tottman, D.R; Makepeace, R.J. (1979). An explanation of the decimal code for growth stages of cereals with illustrations. Annals of Applied Biology, 93, 221-234

Upstone, M.E.; Swann, N.B.; Stichbury, R. (1982). Control of Alopecurus myosuroides in the UK by Autumn application of chlorsulfuron plus methabenzthiazuron in winter wheat. Proceedings 1982 British Crop Protection Conference - Weeds 629-636.

FF4014: A NEW BROAD SPECTRUM CEREAL HERBICIDE BASED ON FLUROXYPYR

J.A. PAUL, P.B. SUTTON, A.M. SKIDMORE

Imperial Chemical Industries PLC, Plant Protection Division, Bear Lane, Farnham, Surrey, GU9 7UB

D.J. SCORER

Dow Chemical Company Limited, King's Lynn, Norfolk PE30 2JD

ABSTRACT

Fluroxypyr, a new selective broad leaved herbicide for cereals, with particularly good activity against *Galium aparine*, has been mixed with the complementary hydroxybenzonitrile (HBN) herbicides ioxynil and bromoxynil in a new formulated product coded FF4014. FF4014 controls all the major cereal broad-leaved weeds including *G.aparine*, *Stellaria media*, *Galeopsis tetrahit*, *Bilderdykia convolvulus*, *Myosotis arvensis*, *Matricaria* spp. and *Polygonum persicaria*. It has a wide margin of crop safety both in terms of rate of application and crop growth stage.

INTRODUCTION

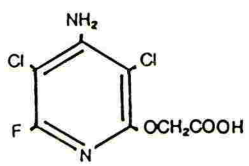
Control of broad leaved weeds is still of paramount importance to the majority of cereal growers in the United Kingdom. A survey of cereal growers in 1984 (PAR, 1984) revealed that *Stellaria media* remains the most prevalent weed but *Galium aparine* is now regarded by farmers as one of the most difficult weeds to eradicate.

Control of *G.aparine* by existing herbicides has been unreliable (Orson, 1984). One of the more recently introduced herbicides which gives excellent control of *G.aparine* and a range of other broad-leaved weeds is fluroxypyr.

Fluroxypyr is a discovery of The Dow Chemical Company and has the following properties.

Chemical and physical properties of fluroxypyr

Structure:



Physical state :	white crystalline solid
Melting point :	232-233°C
Vapour pressure:	9.42×10^{-7} mm Hg at 25°C
Solubilities :	Water 0.091 g/l at 20°C; acetone 41.6 g/l at 20°C.

Toxicology

Tests with fluroxypyr have given the following results:

Acute oral, rat	:	LD50 2405 mg/kg
Percutaneous rabbit	:	LD50 >5000 mg/kg
Acute inhalation rat	:	LC50 >296 mg/m^3 at 4h
Acute intraperitoneal rat male	:	LD50 458 mg/kg
rat female	:	LD50 519 mg/kg
Skin irritancy	:	non-irritant
Eye irritancy	:	slight-irritant
Mutagenicity	:	negative in in vitro and in vivo studies
18 month mouse	:	no observable effect level (NOEL) 80 mg/kg/day
2 year rat	:	NOEL 80 mg/kg/day
No evidence of oncogenicity in either of the above two studies		
Teratology rat	:	NOEL 250 mg/kg/day
2 generation reproductive study	:	no adverse effect on fertility or reproductive performance at 500 mg/kg/day.
Fish toxicity	:	rainbow trout LC50>10 mg/l at 96 h

Crop residues

Low straw residues and negligible grain residues have been detected following application at normal use rates.

Fate in soil

Field studies have shown that fluroxypyr undergoes microbial degradation and indicate that fluroxypyr has a relatively short half-life in soils resulting in no adverse effects on following crops.

Mode of action

When applied post emergence as a foliar spray to susceptible broad leaved weeds, fluroxypyr is rapidly absorbed and readily translocated away from the site of application, inducing auxin-like responses such as leaf curling. Further information on the mode of action of fluroxypyr will be found in the paper by G.E. Sanders et al in these proceedings.

Biological activity

At a rate of 150-200g ai/ha, fluroxypyr gives excellent control of *G.aparine* and a range of other common broad leaved weeds including *B.convolvulus*, *S.media*, *G.tetrahit* and *M.arvensis*.

FF4014 is a mixture containing 90g fluroxypyr as the 1 methylheptyl ester, 100g ioxynil and 100g bromoxynil as octanoate esters in an e.c. formulation. The latter two components provide ideal complementary herbicides to widen the spectrum to include the other major cereal weeds. Both are contact herbicides with some limited translocated action.

FF4014 is marketed in the United Kingdom under the trade name 'Advance'.

This paper describes the efficacy of FF4014 in controlling broad-leaved weeds in winter wheat and in winter and spring barley. Results on crop safety, growth stage of application, and yield effects, both in the presence and absence of weeds, are also presented.

MATERIALS AND METHODS

FF4014 was evaluated on commercially grown cereal crops for activity against naturally occurring weed populations and for crop tolerance. All field trials were of randomised block design with four replicates. Applications were made with hand carried boom sprayers at volumes of 200 to 260 l/ha through 80015 or 110002 Teejets at 2 bars pressure. Weed numbers were assessed by counts made in four 0.25m^2 quadrats per plot. Phytotoxicity to crops was assessed by visual estimations of percentage necrosis plus chlorosis per plot. Grain yields were measured by harvesting plots with a Claas Compact harvester fitted with a plot yield weigher and adjusting to 85% dry matter.

RESULTS AND DISCUSSION

Weed control

Trials carried out by ICI and Dow over the last three years have shown that FF4014 gives excellent control of *G.aparine* at a wide range of weed growth stages from both spring (Table 1) and autumn (Table 2) applications.

TABLE 1

FF4014 - Mean percent *G.aparine* control 8 weeks post spring spray to autumn sown crops.

Year (No.of trials)		1983(1)	1984(2)	1984(2)	1985(2)
Weed size (cm)		20	5-20	40	30
Treatment	Rate l/ha				
FF4014	2.0	100	100	99	97
CMPP salt + HBN esters[1]	4.5	90	95	93	95
CMPP salt + bifenox[2]	4.0	-	82	-	-

In this and all subsequent tables:
1 = 488g mecoprop salt plus 56g ioxynil and 56g bromoxynil per litre.
2 = 462.5g mecoprop salt and 187.5g bifenox per litre.

TABLE 2

FF4014 - Mean percent *G.aparine* control following autumn 1984 applications - dose response and duration of control (3 trials).

DAT		28-31	56-73	100-150
Weed size (cm)		<----------	5 - 10	---------->
Treatment	Rate l/ha			
FF4014	1.0	63	85	92
	1.5	89	92	97
	2.0	87	98	96
CMPP salt + HBN esters[1]	3.5	82	95	96
CMPP salt + bifenox[2]	3.5	62	72	97

Control of S.media, V.persica and Matricaria perforata (Table 3) was also good and compared favourably with standards included in the same trials.

Data for other problem weeds are included in Table 4 following spring applications to autumn sown crops. Against almost all the weeds listed, FF4014 at the 2 l/ha rate gave 90 to 100% control, the exceptions being Chrysanthemum segetum and Veronica hederifolia. The level of control compared favourably with standards.

TABLE 3

FF4014 - Mean percent weed control, 8 weeks post spring spray to autumn sown crops

Weed		S.media		V.persica		M.perforata	
Year		1983/84	1985	1983/84	1985	1983/84	1985
Weed size		4cm to flowering		up to flowering		4-10 leaves	
Treatment	Rate l/ha						
FF4014	2.0	99(13)	100(2)	94(14)	85(3)	93(6)	97(1)
CMPP salt + HBN esters[1]	4.5	91(13)	95(3)	92(14)	91(3)	92(6)	100(1)
CMPP salt + bifenox[2]	4.0	88(5)	82(3)	99(2)	97(3)	57(1)	100(1)

( ) = number of trials

TABLE 4

FF4014 - Mean percent weed control, 8 weeks post spring spray to autumn sown crops.

Rate l/ha Weed (number of trials)	2.0 FF4014	4.5 CMPP salt + HBN esters[1]	4.0 CMPP salt + bifenox[2]
Atriplex patula (1)	100	100	-
Bilderdykia convolvulus (2)	91	78	56
Capsella bursa-pastoris (5)	90	98	-
Chrysanthemum segetum (1)	78	64	-
Galeopsis tetrahit (1)	97	63	-
Lamium amplexicaule (5)	99	84	97
Lamium purpureum (3)	93	90	66
Myosotis arvensis (3)	99	83	-
Thlaspi arvense (3)	98	67	82
Veronica hederifolia (6)	82	83	87

FF4014 in the autumn has proved to be particularly effective when applied to young weed plants in good growing conditions. In such circumstances FF4014 at a lower rate of 1.5 l/ha (Table 5) was effective for the control of all the major broad leaved weed species.

Similarly, in a limited number of trials on spring barley, FF4014 at 1.5 l/ha gave good control of the major broad leaved weeds present, with the exception of Sonchus arvensis, where 2.0 l/ha was necessary for good control (Table 6).

FF4014 achieved moderate control of Viola arvensis and was similar in activity to standards. There was a benefit in increasing the rate from 2.0 to 2.5 l/ha in this situation. For high levels of control of Papaver rhoeas, a mixture of 2 l FF4014 and an Approved formulation of MCPA is recommended.

TABLE 5

FF4014 - Mean percent weed control - autumn applications - spring assessment.

Rate l/ha Weed (number of trials 1983-1985)	1.5 FF4014	2.0 FF4014	3.5 CMPP salt + HBN esters[1]
Aphanes arvensis (1)	98	100	-
Geranium sp. (1)	100	100	100
Lamium purpureum (1)	90	100	-
Matricaria perforata (3)	100	100	100
Myosotis arvensis (3)	100	100	100
Papaver rhoeas (2)	96	100	100
Senecio vulgaris (1)	100	100	100
Sinapsis arvensis (1)	100	100	-
Stellaria media (6)	97	97	92
Urtica urens (1)	100	100	100
Veronica persica (2)	93	86	85

TABLE 6

FF4014 - Percent weed control - 6 weeks after application to spring barley

Rate l/ha Weed (number of trials 1985)	1.0 FF4014	1.5 FF4014	2.0 FF4014	3.5 CMPP salt + HBN esters[1]	3.5 CMPP salt + bifenox[2]
Bilderdykia convolvulus (2)	92	100	100	100	100
Capsella bursa-pastoris (1)	78	100	100	100	100
Matricaria perforata (1)	68	100	100	100	40
Polygonum aviculare (1)	100	100	100	100	77
Polygonum lapathifolium(1)	100	100	100	100	89
Sonchus arvensis (1)	60	47	91	88	88
Stellaria media (2)	100	100	100	100	100
Urtica urens (1)	100	100	100	100	88

Ten trials on winter wheat and eight trials on winter barley in 1983 and 1984 with FF4014 demonstrated substantial yield benefits due to the removal of competition from broad leaved weeds (Table 7).

TABLE 7

FF4014 - Yield benefits in efficacy trials 1983 and 1984.

Rate l/ha	2.0 FF4014	4.5 CMPP salt + HBN esters[1]	(Yield on untreated)
Winter Wheat, 10 trials	+ 0.71 t/ha	+ 0.58 t/ha	(6.3 t/ha)
Winter Barley, 8 trials	+ 0.25 t/ha	+ 0.25 t/ha	(6.3 t/ha)

Crop tolerance

FF4014 and standard herbicides were applied to winter barley and winter wheat at three growth stages, earliest tiller production (GS 13.21), first node detectable (GS 31) and second node detectable (GS 32). Two applications were made to spring barley at tillering (GS 14) and first node detectable (GS 31). In addition to the rates required for weed control, applications were also made twice consecutively to simulate accidental double treatment when spray boom swaths overlap.

Tables 8 and 9 represent trials in the series where some crop damage was caused. On the sensitive winter wheat cv Avalon the effect was negligible even at the 2.0 l x 2 rate of application. Winter barley is often a more delicate crop but only a transient slight tip chlorosis/necrosis was observed. In spring 1985, weather conditions in England were very poor with low night temperatures and prolonged wet periods. Despite these conditions spring barley was only slightly affected by FF4014 and again by 28 DAT this was outgrown. In several trials the standard herbicides were moderately phytotoxic, more so than FF4014. Harvest yields from similar trials carried out in 1983/84 were normal (Table 10).

TABLE 8

FF4014 - Percent phytotoxicity (chlorosis + necrosis). Application at GS 13.21

Treatment	Rate l/ha	W barley cv Panda		W wheat cv Avalon		S barley mean cv Kym & Atem	
	DAT	7	14	7	14	7	14
FF4014	1.0	1	2	0	0	3	0
	1.5	2	3	0	0	10	1
	2.0	3	4	0	0	10	2
CMPP salt + HBN esters[1]	3.5	4	5	0	0	5	0
CMPP salt + bifenox[2]	3.5	9	16	0	5	14	12
Untreated	-	0	0	0	0	0	0

Six trials were laid down with similar treatments, the above four trials suffered some phytotoxicity, a second trial with wheat cv Avalon and a trial on barley cv Igri had no damage.

TABLE 9

FF4014 Percent phytotoxicity (chlorosis + necrosis). Spring 1985 applications to winter wheat, winter barley and spring barley.

Treatment	Rate l/ha	Application DAT_1/T_2*	W barley cv Tipper			W wheat cv Avalon					S barley cv Triumph			
			14/5	22/13	28/19	14/-	29/-	42/7	49/14	63/28	4/-	7/-	27/7	34/14
		GS												
FF4014	1.5	14	-	-	-	-	-	-	-	-	1	7	0	0
	1.5 x 2	14	-	-	-	-	-	-	-	-	7	9	0	1
	1.5	31	-	-	-	-	-	-	-	-	-	-	1	0
	1.5 x 2	31	-	-	-	-	-	-	-	-	-	-	6	0
	2.0	31	0	0	0	0	1	0	0	0	-	-	-	-
	2.0 x 2	31	1	1	1	0	2	0	0	0	-	-	-	-
	2.0	32	0	2	1	-	-	1	0	0	-	-	-	-
	2.0 x 2	32	0	2	1	-	-	1	0	0	-	-	-	-
CMPP salt + HBN esters	3.5	14	-	-	-	-	-	-	-	-	1	5	0	0
	3.5 x 2	14	-	-	-	-	-	-	-	-	4	10	0	0
	3.5	31	-	-	-	-	-	-	-	-	-	-	14	2
	3.5 x 2	31	-	-	-	-	-	-	-	-	-	-	26	2
	4.5	31	0	0	1	0	4	0	0	0	-	-	-	-
	4.5 x 2	31	1	1	0	0	6	0	0	0	-	-	-	-
	4.5	32	1	0	0	-	-	3	5	1	-	-	-	-
	4.5 x 2	32	8	4	1	-	-	10	11	2	-	-	-	-
Untreated	-	-	0	0	0	0	0	0	0	0	0	0	0	0

*T_1 Spring barley = GS14, T_2 Spring barley = GS31,
T_1 Winter wheat and winter barley = GS31, T_2 Winter wheat and winter barley = GS32

Three additional trials were carried out with similar treatment lists on winter barley cv Sonja, winter wheat cv Avalon and spring barley cv Triumph; damage levels were similar to the above.

TABLE 10

FF4014 Harvest grain yield in the absence of weeds as percentage of untreated. Spring 1984 applications to autumn sown crops.

Growth stage at application	FF4014 Rate l/ha	Winter wheat (mean of 2 trials)	Winter barley
12-24	2.0	100	98
12-24	2.0 x 2	100	97
22-25	2.0	100	100
22-25	2.0 x 2	98	97
Untreated (t/ha)	-	(9.6)	(9.8)

In separate experiments, not reported in this paper (ICI, unpublished internal reports), the rainfastness and volatility hazard of FF4014 have been evaluated. Laboratory rainwashing studies have shown that FF4014 is rainfast within one hour of application; FF4014 sprayed and rainwashed plants having similar control figures to sprayed, non-rainwashed plants. Although the three active ingredients in FF4014 are esters, laboratory studies have shown that these esters are of low volatility. Field studies using sensitive indicator plants have confirmed that vapour drift should not pose a hazard to sensitive crops adjacent to FF4014 treated fields.

REFERENCES

Dow (1981), Dowco 433, Broad-Leaf Herbicide. Unpublished - Technical Information.

Ide, S (1984). Fluroxypyr for Galium aparine (cleavers) control in cereals, p.19. Abstracts of papers given at the AAB meeting on 'Understanding cleavers (Galium aparine) and their control in cereals and oilseed rape'.

Orson, J.H. (1984). ADAS results on the control of Galium aparine in cereals, p.14. (IBID).

PAR (Agricultural Research), 1984: survey on cereal growers use of crop protection chemicals in 1984, Volume II - Use of herbicides.

ACKNOWLEDGEMENTS

The authors wish to thank their colleagues within ICI and Dow who carried out the work reported in this paper.

Note

'Advance' is the Trade Mark of The Dow Chemical Company.

THE BIOLOGICAL ACTIVITY OF EL-107 AND ITS MOBILITY AND DEGRADATION IN SOIL

F. HUGGENBERGER, P.J. RYAN

Lilly Research Centre Ltd., Erl Wood Manor, Windlesham, Surrey, GU20 6PH

ABSTRACT

The herbicidal activity of El-107 has been demonstrated in solution culture tests at the very low concentrations of 0.01 - 0.1 g ai/l against important broadleaved weeds common in cereal crops. In these tests, cereals were only affected at the highest concentrations tested of 0.5 - 1.0 g ai/l confirming the wide safety margin observed in field trials. The mobility of El-107 in soil is relatively low. Its chemical persistence in soil is moderate. Based on data summarised in this report it can be estimated that approximately 25% of the El-107 applied remains in the top 2 cm of the soil 4-5 months after a pre-emergence application to winter cereals. Due to the high biological activity of El-107, this amount of chemical is sufficient to assure consistent control of susceptible weeds germinating in spring.

INTRODUCTION

El-107 (N-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide) is a new herbicide for the control of broadleaved weeds in cereals. It is recommended as a pre-emergence treatment for the control of broadleaved weeds in winter cereals at 125 g ai/ha. In combination with grass herbicides providing some control of broadleaved weeds, it is recommended at the reduced application rates of 50-75 g ai/ha. The physical and chemical properties of El-107 and results from field trials were first described by Huggenberger et al. (1982). Additional reports summarising efficacy, selectivity and yield data from field trials including El-107 in France (Casanova et al. 1985), in the United Kingdom (Drinkall and Ryan 1984, Drinkall and Faulkner 1985) and in Germany (Mülle and Kissing 1984) have been published recently.

This report summarises results obtained in petri dish and sand culture studies established to characterise the biological activity of El-107. Results from soil leaching and degradation studies are also presented. Attempts are made to correlate these results with the efficacy and selectivity of El-107 observed in field trials.

MATERIALS AND METHODS

1. Petri dish tests

Seeds of wheat (cv Highbury), barley (cv Sonja), *Matricaria perforata*, *Polygonum persicaria*, *Stellaria media*, *Veronica persica* and *Viola arvensis* were placed on filter paper in petri dishes containing aqueous solutions of El-107 at different concentrations. Throughout the experiment water was added to keep the filter paper moist. Seven days after germination the length of the radicle was measured and the dosage providing fifty percent growth reduction (GR_{50}) determined.

2. Sand culture tests

Seeds of wheat (cv Mardler), barley (cv Sonja) and weed seeds as in petri dish tests were placed in washed sand at a depth of 1 cm. Nutrient solutions containing different concentrations of El-107 or reference products were supplied. Plant weight, air dried after blotting, was measured 25 days after the start of the experiment and the dosage providing fifty percent growth reduction (GR_{50}) determined.

3. Soil leaching study

Plastic columns (diameter 65 mm, length 150 mm) were packed with a loam soil (Table 2) to a bulk density of 0.95 g/ml. The soil was wetted to field capacity by capillary action before the chemicals were applied to the soil surface at rates equivalent to 50, 125 and 250 g ai/ha for El-107, 480 g ai/ha for linuron and 20 g ai/ha for chlorsulfuron. The soil columns were imbedded vertically in sand for easy drainage of excess water and the soil surface of the columns exposed to ambient temperature and natural rainfall in the open. The experiment was started on November 21st, 1984. Rainfall and soil temperature were monitored throughout the experiment (Figure 1). At monthly intervals the distribution and total amount of chemicals remaining in six soil columns were determined by bioassay. *Brassica napus* and *Lolium multiflorum* were used as bioassay species for El-107 and linuron, and chlorsulfuron respectively.

4. Soil degradation studies

Degradation data from the soil leaching study were evaluated, assuming first order kinetics, by fitting decline curves calculated by regression analysis. Additional soil decline curves of El-107 were established from four field trials carried out in France. In these trials El-107 was applied as a pre-emergence treatment to winter cereals according to standard methodology for establishing small plot replicated field trials. Soil samples were taken at various time intervals to a depth of 5-10 cm until approximately one year after application. El-107 was extracted by refluxing with methanol/water, followed by partitioning into dichloromethane and purification on an alumina F20 column with quantification by hplc with u.v. detection at 254 nm. Particle size distribution and organic matter content of soils were determined following standard laboratory methodology.

5. Products

In all studies chemicals were used as formulated products: El-107, 50SC, linuron 50WP, chlorsulfuron 75DF.

RESULTS

1. Petri dish and sand culture tests

Radical growth of seeds of *Matricaria perforata*, *Polygonum persicaria*, *Stellaria media*, *Veronica persica* and *Viola arvensis* was reduced by 50 percent when exposed to concentrations of El-107 between 0.01 to 0.08 mg ai/l in petri dish tests. Symptoms of toxicity included swelling of roots and hypocotyls, asymmetrical growth of tissues, browning of roots and vascular tissue in the hypocotyl and subsequent plant death.

Effects of El-107 on developing seedlings of wheat and barley were observed only at the highest rates tested 0.5 and 1.0 mg ai/l which are near the limit of solubility of El-107 in water. The GR_{50} for wheat and barley was greater than 0.5 mg ai/l El-107.

El-107 had little effect on the germination of cereal or weed seeds.

TABLE 1

Concentrations of El-107, chlorsulfuron and linuron reducing the development of different seedlings by 50% (GR_{50}) in sand culture tests.

	GR_{50} mg/l		
	El-107	Chlorsulfuron	Linuron
Wheat (cv Mardler)	1.62	6.11	6.45
Barley (cv Sonja)	2.03	3.47	6.43
Matricaria perforata	0.10	0.76	1.18
Polygonum persicaria	0.07	0.50	0.55
Stellaria media	0.07	0.25	0.85
Veronica persica	0.05	1.37	5.27
Viola arvensis	0.11	1.45	4.40
Solubility in water (mg/l) (Pesticide Manual 1983)	1-2	100-125	81

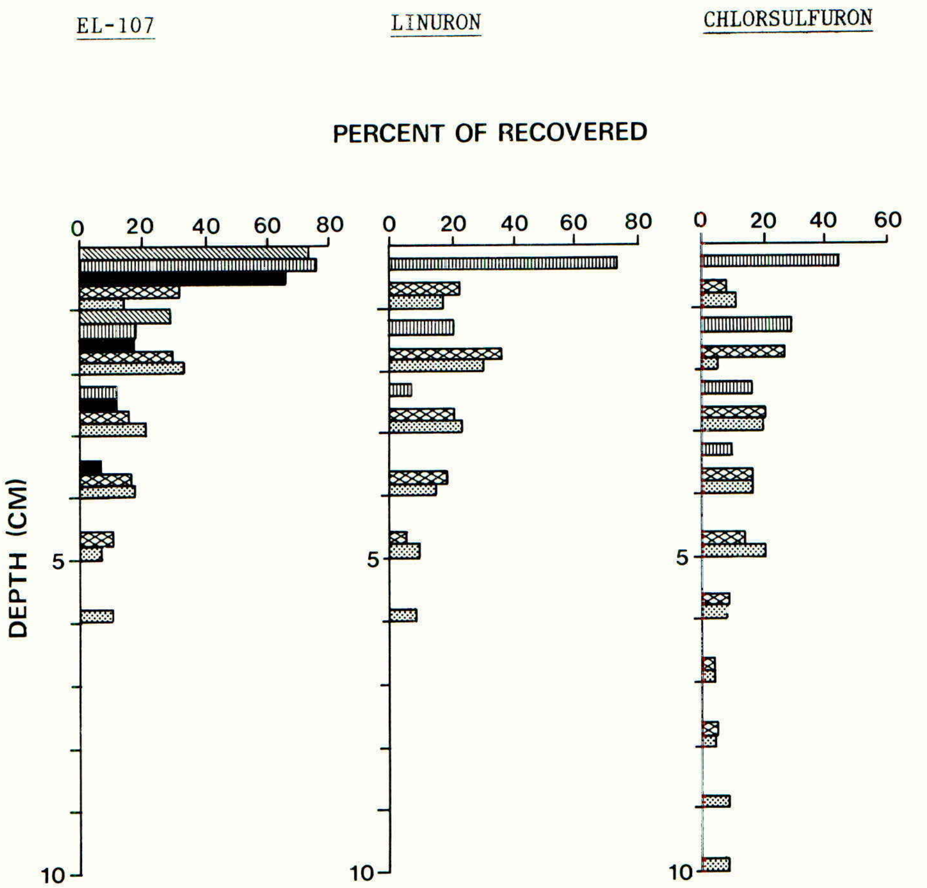
Results obtained in sand culture tests with El-107, chlorsulfuron and linuron are summarised in Table 1. GR_{50} values for different weeds with El-107 were comparable to values found in petri dish tests. Plant weight of wheat or barley was only affected at 0.5 mg ai/l El-107, the highest rate tested. Extrapolated GR_{50} values following a probit analysis are close to the limit of solubility of El-107 in water for wheat and barley.

Comparing results of El-107 with reference products used for selective weed control in cereals, it becomes clear that El-107 shows the highest level of herbicidal activity against the weeds tested. The safety margin between efficacy against weed and injury to crop seedlings was also the largest for El-107.

2. Soil leaching study

FIGURE 1

Distribution of El-107, linuron and chlorsulfuron in a soil leaching study.



	Time after application (month)	Cumulative rainfall (mm)	Soil temperature (°C) mean (min/max)
	1	85	+ 5.17 (+3/+8)
	2	125	- 0.63 (-2/+2)
	3	190	+ 1.38 (-2/+6)
	4	208	+ 3.83 (-1/+7)
	5	265	+ 9.60 (+4/+18)

The distributions of El-107, linuron and chlorsulfuron in soil columns at different times after application are shown in Figure 1. The results are given as average percent of chemical detected per 1 cm segment. For El-107 the distribution is reported only for the application rate equivalent to 125 g ai/ha. As predicted by the model developed by Oddson et al. (1970) different application rates of El-107 did not affect the relative distribution of the chemical detected in the soil columns but only increased the absolute amounts detected in each section. As expected the chemicals are progressively washed into lower sections of the soil columns. The distribution patterns of El-107 and linuron were very similar throughout the experiment. For El-107 and linuron approximately 50 percent of the total chemical detected remained in the top 2 cm of the soil columns 4-5 months after application. Chlorsulfuron was clearly more mobile. It leached more rapidly from the top of the soil column and penetrated deeper than El-107 or linuron.

3. Soil degradation studies

TABLE 2

Soil parameters and half-lives of El-107 in soil.

Application rate g ai/ha	Particle size (%) Sand	Silt	Clay	Organic matter (%)	Half-life (days)	Correlation Coefficient
Soil leaching study						
50	43	50	17	3.2	95	0.98
125					113	0.97
250					123	0.99
Field studies						
125	79	6	14	0.8	104	0.96
	61	12	26	1.2	75	0.99
250	69	8	22	2.6	103	0.94
	52	20	27	1.4	107	0.96

All correlation coefficients were significant at the 1% level of probability.

Results from soil degradation studies with El-107 are summarised in Table 2. Half-lives of El-107 range from 2.5 to 4 months. High correlation coefficients indicate that first order kinetics adequately describe the degradation of El-107 in soil. Half-lives calculated from total amounts of chemical detected by bioassay at different time intervals in the soil leaching study and half-lives calculated from data obtained by chemical analysis from four field studies are in good agreement. Half-lives calculated from studies reported here are shorter than earlier estimates of 5-6 months (Huggenberger et al. 1982). Early half-life calculations for El-107 were made from field degradation studies carried out in Indiana USA. Colder temperatures during winter probably lead to generally lower degradation rates. Analysis of soil samples from other European field trials indicates that the degradation of El-107 in light sandy soils may be slower than in more typical agricultural soils as summarised in this report. The chemical persistence of El-107 in soil can be considered as moderate.

The degradation of linuron in the soil leaching study was also well described by first order kinetics. The half-life calculated was 3 months (91 days) with a correlation coefficient of 0.99, significant at the 1% level of probability. This degradation rate is similar to values reported elsewhere (Maier-Bode and Härtel 1981).

The degradation of chlorsulfuron in the soil leaching study did not follow first order kinetics. The chemical did not degrade between November and January (January 21st, 100% recovered). Little degradation took place between January and March (March 21st, 85% recovered). Between March and April however degradation was rapid (April 21st, 40% recovered). As reported by Walker and Brown (1983), degradation rates of chlorsulfuron appeared to be related to soil temperatures (Figure 1).

DISCUSSION

In the soil leaching study 70% of El-107 applied was recovered from the top 1 cm soil section and 30% from the second 1 cm section one month after application. Assuming the chemical is distributed evenly in each soil section the total concentration of the chemical adsorbed and in solution would be 0.88 µg ai/ml in the top 1 cm section and 0.38 µg ai/ml in the second 1 cm section following an application of El-107 at 125 g ai/ha. It can be assumed that herbicides with low vapour pressures such as El-107 (Lilly Research Laboratories, unpublished report), linuron and chlorsulfuron (Pesticide Manual 1983) need to be available in solution in soil water in order to be biologically active (Guth et al. 1977). An adsorption study was carried out with El-107 with a soil similar to the one used in the soil leaching study (Lilly Research Laboratories, unpublished report). A Freundlich adsorption isotherm was fitted to the data points:

$$S = KC^{1/N}$$

Where S is the concentration of the chemical adsorbed, C the concentration of the chemical in solution and K and N are constants. Values of $K = 5.7$ and $1/N = 1.03$ were determined in this experiment. At equilibrium a rough estimate of the herbicide in solution for the top 1 cm section can be calculated as follows:

$$\beta S + \Theta C = 0.88\ \mu g\ ai/ml$$

Setting 1/N to unity for ease of calculation and assuming an average volumetric water content $\Theta = 0.3$ and a uniform bulk density in each section $\beta = 0.95$ g/ml, the average concentration of El-107 in the soil solution would be 0.15 µg ai/ml in the top 1 cm section and 0.07 µg ai/ml in the second 1 cm section. These concentrations are clearly sufficient to severely affect the development of susceptible weeds as shown in solution culture studies (Table 1) and in the bioassay of the soil column. Under field conditions the concentrations of herbicides in the soil solution can vary widely depending on climatic and soil conditions (Gerber et al. 1983). They are likely to be at least double the concentrations calculated above because in normal field soils only approximately half the volume consists of solid soil particles. As most weeds emerge from within 2 cm from the soil surface (Chancellor 1964), the rough estimates and assumptions made above seem, however, to be consistent with the excellent control of susceptible weeds observed in the field with El-107. The amount of El-107 likely to be in solution in soil water is also clearly lower than the level necessary to affect the development of cereals. This would explain the complete selectivity of El-107 in the field to all cereals even when the product is incorporated.

In the soil leaching study approximately 25% of the El-107 applied remained in the top 2 cm of the soil 4-5 months after application. Following calculations as above the corresponding concentration of El-107 in the soil solution would be approximately 0.03 µg ai/ml 4-5 months after application of 125 g ai/ha. This concentration is still sufficient to affect the development of weeds as shown in petri dish tests and soil column bioassays. As mentioned above the concentrations in normal field soils are likely to be considerably higher and therefore well within the range of GR_{50} values as determined in sand culture tests (Table 1). Field observations that El-107 consistently controls spring germinating weeds when applied as pre-emergence treatment in winter cereals can therefore be explained by its very high biological activity and relatively low soil mobility. Linuron was similar in mobility and degradation to El-107. A calculation as above indicates however that the amount of linuron remaining in the top 2 cm of the soil is unlikely to be sufficient to consistently control spring germinating weeds following an autumn application at its recommended rate. This is consistent with our field experience when using linuron in combination with trifluralin for weed control in winter cereals at 480 + 960 g ai/ha. Based on results presented here, it seems equally unlikely that sufficient chlorsulfuron would remain in the top 2 cm of soil to consistently control spring germinating weeds following an autumn application of the chemical.

Due to its very high biological activity sufficient El-107 may remain available to affect susceptible crops, such as rapeseed when seeded directly into the treated soil layer by direct drilling or following minimal cultivation 8-10 months after application. To avoid potential reductions in crop stand, it is therefore recommended to mouldboard plough to at least 20 cm before seeding susceptible following crops.

REFERENCES

Casanova, A.; Leca, J.L.; Provė, P. (1985) Qu 'est-ce que le Cent-7. Protection des Vegeteaux (in press).

Chancellor, R.J. (1964) The depth of weed seed germination in the field. Proceedings 7th British Weed Control Conference 2, 607-613.

Drinkall, M.J.; Ryan, P.J.; (1984) Development of El-107 a new selective cereal herbicide. Proceedings Crop Protection in Northern Britain 1984, 10-15.

Gerber, H.R.; Nyffeler, A.; Green, D.H.; (1983) The influence of rainfall, temperature, humidity and light on soil - and foliage - applied herbicides. Aspects of Applied Biology 4, 1983 Influence of environmental factors on herbicide performance and crop and weed biology, 1-14.

Guth, J.A.; Gerber, H.R.; Schlaepfer, Th. (1977) Effect of adsorption, movement and persistence on the biological availability of soil applied pesticides. Proceedings 1977 British Crop Protection Conference - Pests and Diseases, 961-970.

Huggenberger, F.; Jennings, E.A.; Ryan, P.J.; Burow, K.W. (1982) El-107 a new selective herbicide for use in cereals. Proceedings 1982 British Crop Protection Conference - Weeds 1, 47-52.

Maier-Bode, H.; Härtel, K. (1981) Linuron and monolinuron. Residue Reviews 77, 154-178.

Mülle, G.; Kissing, W. (1984) El-107, ein neues Bodenherbizid zur Bekämpfung dikotyler Unkräuter im Getreide. Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz, Sonderheft X, 311-318.

Oddson, J.K.; Letey, J.; Weeks, L.V. (1970) Predicted distribution of organic chemicals in solution and adsorbed as a function of position and time for various chemical and soil properties. Soil Science Society of America Proceedings 34, 412-417.

The Pesticide Manual (1983) Worthing, C.R. (editor). The British Crop Protection Council.

Walker, A.; Brown, P.A. (1983) Measurement and prediction of chlorsulfuron persistence in soil. Bulletin of Environmental Contamination Toxicology 30, 365-372.

CYANAZINE + CLOPYRALID - A NOVEL CEREAL HERBICIDE DEVELOPED FOR FLEXIBILITY AND VERSATILITY

P. H. MOULT

Shell Chemicals UK Limited, Agricultural Division, 39/41 St Mary's Street Ely, Cambridgeshire, CB7 4HG, UK

A. R. THOMPSON

Dow Chemical Company Limited, Latchmore Court, Brand Street, Hitchin, Hertfordshire, SG5 1HZ, UK

ABSTRACT

Cyanazine + clopyralid was evaluated both alone and in tank-mixture with reduced rates of a range of currently marketed herbicides in 31 autumn and spring applied replicated field trials. The trials were carried out on commercially grown cereal crops in England and Scotland during the period 1983-85. In addition, the majority of the herbicide mixtures evaluated were included in 30 replicated fungicide compatibility field trials. The herbicide mixtures gave good to excellent control of a number of broad-leaved weed species resistant to phenoxyalkanoic, some substituted urea and other herbicides. The level of control achieved for a particular species was governed by choice and rate of mixture partner. Suppression of 2 grass weed species was also recorded. Variation of the spray volume applied had no effect on overall broad-leaved weed control. The mixtures evaluated were found to be biologically compatible with a range of fungicides $\pm$ growth regulator.

INTRODUCTION

The resistance of certain broad-leaved weed species to the phenoxy-alkanoic herbicides is well known (Attwood 1978) and the continued widespread use of these materials and of others such as some of the substituted ureas has resulted in the frequent occurrence of resistant species in cereal crops. It has been shown (Luckhurst et al 1972) that the addition of low rates of cyanazine to reduced rates of MCPA and of dichlorprop resulted in very good control of the resistant species *Veronica* spp. and "*Matricaria*" spp., and in the case of MCPA of *Stellaria media* and *Polygonum persicaria*.

Trials involving mixtures of reduced rates of clopyralid and of mecoprop or dichlorprop have demonstrated enhancement in activity, particularly against members of the Compositae family (Brown & Uprichard 1976). Increased control of these and of Polygonaceae species by addition of clopyralid to mecoprop has also been demonstrated (Gilchrist & Page 1976), but resistant species such as *Veronica* spp., *Aphanes arvensis*, *Myosotis arvensis* and *Viola arvensis* were not adequately controlled by the mixture.

In recent years, the use of "mixer" rather than broad spectrum products for broad-leaved weed control in cereals has increased substantially, an indication of the need to match herbicide usage with weed spectrum. Cyanazine and clopyralid have different modes of action. There is both foliar and root uptake of cyanazine resulting in the disruption of photosynthetic processes in susceptible species. Clopyralid is mainly leaf-absorbed and is translocated throughout plants inducing auxin-type responses in susceptible species. It was felt that the combination of cyanazine + clopyralid ('Coupler') in tank-mixture with reduced rates of phenoxyalkanoic or other herbicides would provide an effective, flexible and versatile alternative to the "mixer" products currently available.

This research report presents the results of field trials carried out with the product in England and Scotland during the period 1983-85.

MATERIALS AND METHODS

Twenty nine replicated trials were carried out on commercial cereal crops in England and Scotland to evaluate the various herbicide tank-mixtures in the period 1983-85. The trials (14 winter wheat, 12 winter barley and 3 spring barley) were all of the randomised block design with 3 or 4 replicates and a plot size of 20-48 square metres. The crop growth stages at application ranged from 21-25 (Tottman & Makepeace 1979) in the autumn and 23-33 (majority 30-31) in the spring. Weed sizes at autumn applications were all Yp (2-4 true leaves) and in the spring fell within the range of Fb - F (established plants with 5 or more true leaves - flowering).

A further 30 replicated trials (19 winter wheat, 9 winter barley and 2 spring barley) were carried out in 1984/85 to evaluate the compatibilities of most of the herbicide tank-mixtures with a growth regulator and/or fungicides. These trials were also of the randomised block design, the majority had 2 replicates and a plot size of 19 square metres. Autumn applications were made at crop growth stage 22-25, but spring applications were deliberately delayed such that the crops were at or just beyond the latest recommended growth stage for the herbicide mixture partner. The growth stages were:- mecoprop 31-32, MCPA 31, dichlorprop 31, 2,4-D 31, mecoprop + MCPA 30, fluroxypyr 33.

In addition, 2 trials were carried out on winter wheat to evaluate a range of spray volumes for 2 of the herbicide mixtures. These applications were made in the spring using a vehicle-mounted modified Hardi 12 m sprayer with 110° fan jets at 50 cm spacing at a pressure of 300 kPa. All other applications were made using van der Weij small plot precision sprayers at a pressure of 280 kPa and a spray volume of 280 l/ha (1983 and 1984) or 200 l/ha (1985) delivered through 80° fan jets. Phytotoxicity was assessed in the compatibility trials using a 1-9 scale where 1 = no damage, 9 = no crop and 5 = maximum commercially acceptable. Broad-leaved weed control was assessed by means of a visual estimate of % ground cover by species for a whole plot at 8 - 12 weeks after spring application and at 6 months after autumn application. Grass weed control was assessed by means of head or panicle counts in appropriate numbers and sizes of quadrats per plot. Most of the trials (except fungicide compatibility) were harvested using modified Claas Compact or Comet combines and yields were corrected to 15% moisture.

The formulation of cyanazine + clopyralid used in 1983 was a water dispersible granule containing 700 + 120 g/kg. From 1984, tank-mixtures of a suspension concentrate containing 500 g/litre cyanazine and a liquid formulation containing 100 g/litre clopyralid were used. The herbicides used as mixture partners were commercially available formulations of mecoprop (570 g/litre K salt), MCPA (250 g/litre Na + K salts), dichlorprop (540 g/litre K salt), 2,4-D (500 g/litre diethanolamine salt), dichlorprop + MCPA (360 g/litre K salt + 180 g/litre Na salt), fluroxypyr (200 g/litre

1-methyl heptyl ester), bifenox + mecoprop (188 + 463 g/litre) and isoproturon (500 g/litre). Commercial standards used for comparison were bromoxynil + ioxynil (380 g acid equivalent/litre octanoate esters) in tank-mix with mecoprop, dichlorprop or isoproturon and a formulation containing bromoxynil + ioxynil + mecoprop (56 + 56 + 448 g/litre). The growth regulator, insecticide and fungicides used in the compatibility trials were commercially available formulations or recommended tank-mixtures and are listed in Tables 2 and 5 or are referred to in the text.

RESULTS

The following is a list of the codes for weed species used in the results tables and gives their full names:-

Alo my	Alopecurus myosuroides	Myo ar	Myosotis arvensis
Ape sv	Apera spica-venti	Pap rh	Papaver rhoeas
Aph ar	Aphanes arvensis	Poa tr	Poa trivialis
Che al	Chenopodium album	Pol av	Polygonum aviculare
Gal ap	Galium aparine	Pol pe	Polygonum persicaria
Gal te	Galeopsis tetrahit	Ste me	Stellaria media
Lam pu	Lamium purpureum	Ver pe	Veronica persica
Leg hy	Legousia hybrida	Ver ss	Veronica spp.
Mat ss	"Matricaria" spp.	Vio ar	Viola arvensis

"Matricaria" spp. includes the species Matricaria perforata, Chamomilla recutita and Chamomilla suaveolens.

The following abbreviations have been used for certain herbicide treatments in the results tables:-

cyan + clop	= cyanazine + clopyralid	flurox	= fluroxypyr
bif	= bifenox	2,4-DP	= dichlorprop
mec	= mecoprop	HBNs	= hydroxybenzonitriles

Autumn application

The application of cyanazine + clopyralid at 0.35 + 0.06 kg a.i./ha in the autumn resulted in acceptable control (greater than 85%) of "Matricaria" spp. and Myosotis arvensis, but addition of a mixture partner was required to give acceptable control of Stellaria media, Veronica spp. and Viola arvensis (Table 1). The addition of mecoprop (1.20 kg a.i./ha gave improved control of the mecoprop-resistant species M. arvensis, Veronica spp. and Viola arvensis. Addition of fluroxypyr (0.20 kg a.i./ha) gave improved control of Viola arvensis, a fluroxypyr-resistant weed. The addition of bifenox + mecoprop (1.37 kg a.i./ha) gave excellent control of all species in the trials. All treatments gave significant yield increases against untreated with no significant differences between treatments.

The addition of the fungicides and insecticide listed in Table 2 to mixtures of cyanazine + clopyralid with mecoprop or fluroxypyr had little or no effect on broad-leaved weed control. No unacceptable phytotoxicity was observed during the season in any of the 4 trials.

Spring application

Cyanazine + clopyralid applied in the spring at 0.35 + 0.06 kg a.i./ha in winter cereals gave complete control of "Matricaria" spp., but failed to give acceptable control of Galium aparine, Myosotis arvensis, S. media and Viola arvensis (Table 3). There was very good control of a number of phenoxyalkanoic-resistant species following the addition of reduced rates of these products to cyanazine + clopyralid. Examples are M. arvensis, Papaver rhoeas, Veronica spp. and Viola arvensis. Similarly, addition of fluroxypyr at reduced rates to cyanazine + clopyralid gave excellent control of Veronica spp. and good control of Viola arvensis. Control of all these species was comparable to that given by the hydroxybenzonitrile standards.

TABLE 1

Autumn application - mean of 3 trials - % weed control and % of untreated yield (number of sites, no figure = 1 site)

Weed species		Mat ss	Myo ar	Ste me	Ver ss	Vio ar	Yield
Untreated % cover or t/ha		39(2)	24	23(3)	24	69	4.3(3)
cyan + clop	0.35 + 0.06	95(2)	90	82(3)	51	58	150(3)
+ bif + mec	1.37	96(2)	99	90(3)	99	92	148(3)
*+ bif + mec	1.37	99(2)	100	88(3)	96	89	149(3)
+ mecoprop	1.20	96(2)	100	90(3)	65	81	147(3)
+ fluroxypyr	0.20	93(2)	93	97(3)	58	84	149(3)
HBNs + mec	0.57 + 1.20	97(2)	97	94(3)	95	82	155(3)

* = cyanazine + clopyralid at 0.23 + 0.04 kg a.i./ha

TABLE 2

Autumn application - fungicide compatibility - % overall broad-leaved weed control

	kg a.i./ha	mecoprop 2.28	fluroxypyr 0.20
Untreated % cover		91	103
cyanazine + clopyralid +	0.35 + 0.06	84	80
+ propiconazole	0.125	84	92
+ prochloraz	0.40	83	89
+ triadimenol	0.125	85	83
+ fenpropimorph	0.75	81	79
+ chlormequat + carbendazim	0.48 + 0.125	91	86
+ benomyl	0.25	95	85
+ fenvalerate	0.02	89	77
+ triadimefon	0.125	91	88

Suppression of the grass weed species Apera spica-venti and Poa trivialis was observed following spring application of cyanazine + clopyralid mixtures in winter cereals. There was no suppression of grass weeds following application of the hydroxybenzonitriles (Table 3).

Cyanazine + clopyralid was applied at 2 rates (0.35 + 0.06 and 0.23 + 0.04 kg a.i./ha) in tank-mixture with the recommended rate of isoproturon. Both rates gave acceptable control of the isoproturon-resistant species Aphanes arvensis, Veronica spp. and Viola arvensis, but the addition of mecoprop was required for Galium aparine control (Table 4). There was no effect on the level of control of Alopecurus myosuroides following autumn or spring applications.

A reduced rate of cyanazine + clopyralid (0.23 + 0.04 kg a.i./ha) was applied on spring cereals in tank-mixture with the same range of herbicides as was evaluated on winter cereals. A similar pattern of good to excellent control of phenoxyalkanoic- or fluroxypyr-resistant species by the mixtures was observed, e.g. Polygonum aviculare, Polygonum persicaria, Veronica persica and Viola arvensis (Table 6). Levels of control were again comparable with the hydroxybenzonitrile standards. Yield responses relative

TABLE 3

Spring application - winter cereals - mean of 18 trials - % weed control and % of untreated yield (number of sites no figure = 1 site)

Weed species		Aph ar	Gal ap	Leg hy	Mat ss	Myo ar	Pap rh	Ste me	Ver ss	Vio ar	Ape sv	Poa tr	Yield
Untreated		10	45(3)	10	20(9)	15(4)	42(2)	36(13)	14(10)	23(9)	45*	10	6.1(10)
cyan+clop	0.35+0.06	-	0	-	100(1)	68(1)	-	72(3)	-	35(1)	-	-	101(3)
+ mec	1.71	-	89	-	100(2)	84(2)	78	98(6)	79(4)	66(3)	-	-	98(7)
	2.28	-	100	-	100(2)	85(2)	80	100(6)	83(4)	72(3)	-	-	102(7)
	2.40	60	99	100	100(4)	98(2)	100	99(4)	97(5)	91(4)	60	-	113(3)
+ MCPA	1.08	-	89	-	97(2)	96(2)	49	91(6)	79(4)	63(3)	-	-	97(7)
	1.45	95	-	100	100(4)	97(2)	100	100(3)	99(4)	92(4)	40	-	96(2)
+ 2,4-DP	1.62	-	98	-	100(2)	88(2)	70	96(6)	73(4)	65(3)	-	-	98(7)
	1.90	74	-	100	100(2)	97(2)	99	100(3)	100(4)	92(4)	56	-	94(2)
+ 2,4-D		89	-	98	100(4)	98(2)	98	97(3)	99(4)	84(4)	64	-	109(2)
+ mec+MCPA	2.4+0.5	84	99	98	100(4)	100(2)	100	100(4)	96(5)	90(4)	47	-	121(3)
+ DP+MCPA	1.9	92	-	100	100(4)	100(2)	100	99(3)	97(4)	93(4)	35	-	106(2)
+ bif+mec	1.3	79	99	98	99(4)	99(2)	100	99(4)	99(5)	87(4)	49	-	114(3)
+ flurox	0.15	79	100	100	100(4)	100(2)	98	100(3)	99(4)	91(4)	69	-	101(2)
	0.18	-	98	-	97(3)	-	-	99(3)	98(1)	89(2)	-	70	-
	0.20	-	100(2)	-	100(2)	100(2)	63	100(7)	95(5)	64(3)	-	-	103(8)
Standards:-													
A	2.52	-	93	-	89(3)	82	-	95(4)	88(2)	79(3)	-	0	92(1)
	2.80	13	98(2)	80	95(7)	87	100	93(6)	93(5)	77(5)	14	0	136(2)
B	0.57+2.1	-	100	-	100(2)	98(2)	99	99(6)	92(4)	77(3)	-	-	101(7)
C	0.57+1.4	-	100	-	100(2)	97(2)	94	84(6)	93(4)	69(3)	-	-	99(7)

Untreated as % cover or t/ha except * as heads/sq. m.

Standards:- A & B = ioxynil + bromoxynil + mecoprop; C = ioxynil + bromoxynil + dichlorprop

TABLE 4

Spring application - winter cereals - mean of 5 trials - % weed control and % of control yield (number of sites, no figure = 1 site) * autumn applied, isoproturon at 2.5 and mecoprop at 1.2 kg a.i./ha. ** Untreated as heads/sq m

Weed species	Aph ar	Gal ap	Lam pu	Mat ss	Myo ar	Ste me	Ver ss	Vio ar	Alo my**		Yield
Untreated % cover or t/ha	28	15(2)	8	26(2)	13	57(3)	10(4)	9	986*	416(2)	4.1(3)
isoproturon 2.1	44	43(2)	73	100(2)	77	97(3)	73(4)	84	92	86(2)	130(3)
+ cyan+clop 0.35+0.06	94	84(2)	97	100(2)	95	98(3)	92(4)	87	92	90(2)	126(3)
+ cyan+clop 0.23+0.04	89	73(2)	94	100(2)	99	97(3)	89(4)	92	95	79(2)	128(3)
+ c+c + mec 0.23+0.04+2.16	88	92(2)	88	99(2)	98	97(3)	89(4)	96	96	78(2)	129(3)
+ HBNs 0.254	97	74(2)	88	100(2)	85	97(3)	95(4)	91	96	87(2)	138(3)

TABLE 5

Spring application - fungicide compatibility - winter cereals - mean of 24 trials (no. of sites,no fig. = 1 site)

cyanazine+clopyralid + 0.35 + 0.06	mecoprop 2.4	mecoprop + chlormequat 2.4 + 1.6	mecoprop + MCPA* 2.4 + 0.5	mecoprop + MCPA + chlormequat 2.4+0.5+1.6	MCPA 1.45	2,4-D 0.79	dichlorprop 1.9	fluroxypyr 0.2
	% overall broad-leaved weed control							
Untreated % cover	101(3)	96(3)	58(4)	101(3)	84(3)	87(3)	88(2)	119(3)
Without f/cide	97	93	96	98	99	94	99	100
With f/cide (range)	95-98	89-97	95-98	96-98	97-100	92-96	98-99	99-100
	Phytotoxicity scores (1 = no damage, 5 = maximum commercially acceptable)							
+ A 0.375	-	-	-	4.5	-	-	-	4.0
+ B 0.750	-	-	4.0	4.8	-	-	4.5	-
+ C 0.550	-	-	4.0	-	-	-	-	-
+ D 0.125	-	-	4.0	4.5	-	-	-	-
+ E 0.375	-	-	-	4.0	-	-	-	-
+ F 0.225	-	-	-	4.3	-	-	-	-
+ G 0.306	4.4	-	-	4.3	-	-	-	4.3
+ H 0.125 + 0.375	-	-	4.1(2)	4.8	-	-	-	4.0
+ I 0.125 + 0.375	-	-	4.3(2)	4.3	-	-	5.0	5.0

*includes 2 spring barley trials at 0.23 + 0.04 + 1.8 + 0.5 kg a.i./ha. A = propiconazole + tridemorph; B = fenpropimorph; C = prochloraz + carbendazim; D = triadimenol; E = triadimefon + carbendazim; F = propiconazole + carbendazim; G = flutriafol + carbendazim; H = triadimenol + tridemorph; I = propiconazole + tridemorph.

to untreated following spring applications on winter or spring cereals varied dependent upon the density of weed population.

The addition of the plant growth regulator chlormequat and/or the range of fungicides listed in Table 5 to the herbicide mixtures evaluated had no effect on broad-leaved weed control. Other fungicides were also evaluated but are not listed as their addition to the herbicide mixtures had no effect on weed control and did not result in phytotoxicity. They were prochloraz, carbendazim, triadimefon, propiconazole, fenpropimorph + carbendazim and triadimefon + carbendazim + prochloraz. Phytotoxicity scores are presented only for those treatments which scored 4 or above during the season. The scores initially were for scorch, which was transient in the majority of cases with no damage recorded subsequently. However, in the case of the tank-mix of propiconazole + tridemorph with the mecoprop + MCPA, mecoprop + MCPA + chlormequat and dichlorprop mixtures the damage persisted and resulted in shortening and thinning or delayed ripening evident at harvest. Similarly, the tank-mix of triadimenol + tridemorph with the mecoprop + MCPA mixture resulted in shortening and thinning. The addition of chlormequat to the mecoprop + MCPA mixture increased the level of damage recorded.

TABLE 6

Spring application - spring cereals - mean of 3 trials - % weed control and % of control yield (number of sites, no figure = 1 site)

Weed species		Che al	Gal te	Pol av	Pol pe	Ste me	Ver pe	Vio ar	YIELD
Untreated % cov or t/ha		33	6	19(2)	51	33(3)	16	16	6.2(3)
cyan + clop	0.23+0.04	-	-	-	-	-	-	-	-
+ mecoprop	1.8	-	93	90(2)	-	100	-	-	107(2)
	2.4	96	-	-	95	96(2)	99	89	95(1)
+ MCPA	1.1	-	97	88(2)	-	98	-	-	100(2)
	1.45	99	-	-	100	97(2)	92	95	96(1)
+dichlorprop	1.9	99	98	92(2)	100	95(3)	92	87	106(3)
+ 2,4-D	0.5	-	91	90(2)	-	82	-	-	110(2)
	0.79	100	-	-	99	86	89	89	100(1)
+ mec + MCPA	1.8+0.5	-	92	97(2)	-	100	-	-	112(2)
	2.4+0.5	99	-	-	100	99(2)	93	94	98(1)
+2,4-DP+MCPA	1.9	100	97	94(2)	100	98(3)	95	89	102(3)
+ bif + mec	1.3	99	98	95(2)	99	98(3)	98	97	100(3)
+ fluroxypyr	0.15	88	98	98(2)	99	98(2)	-	-	107(2)
	0.20	-	-	-	-	99	98	93	99(1)
Standards:-									
A	1.96	98	-	-	98	95	-	-	-
	2.80	-	-	-	-	99	100	93	97(1)
A + MCPA	1.96+0.9	-	98	98(2)	-	100	-	-	109(2)

A = ioxynil + bromoxynil + mecoprop

Variation in the spray volume of mixtures of cyanazine + clopyralid with mecoprop or fluroxypyr had no effect on the level of overall broad-leaved weed control (Table 7). However, control of Viola arvensis and Veronica spp. was reduced at 120 litres/ha, particularly at the higher speed evaluated (12 kph).

TABLE 7

Spring application - winter cereals - mean of 2 trials - % overall broad-leaved weed control (untreated 63% cover)

cyanazine + clopyralid + 0.35 + 0.06	mecoprop 2.28	fluroxypyr 0.20
at 120 litres/ha (jet 02110, 8 kph)	95	95
at 240 litres/ha (jet 04110, 8 kph)	95	96
at 300 litres/ha (jet 05110, 8 kph)	96	96
at 120 litres/ha (jet 03110, 12 kph)	95	93

DISCUSSION

The results of 3 years' trials demonstrate the effectiveness of cyanazine + clopyralid, either alone or in tank-mixture with reduced rates of a suitable partner, for the control of broad-leaved weed species resistant to the phenoxyalkanoic, some of the substituted urea and other herbicides. The level of control achieved for a particular species is governed by the choice and rate of mixture partner applied. Weeds were at advanced growth stages at application in the majority of trials and this is reflected in the poor control of some species at the lowest rates evaluated. The majority of the herbicide mixtures evaluated were included in fungicide compatibility trials and all combinations were found to be acceptable in terms of efficacy and selectivity with the exception of those involving tank-mixtures of tridemorph with propiconazole or triadimenol.

The unique combination of cyanazine + clopyralid with recommendations for tank-mixture with a wide range of herbicides and fungicides ± growth regulator therefore provides an extremely effective and versatile alternative to the "mixer" products currently available.

ACKNOWLEDGEMENTS

The authors would like to thank the many farmers who provided trial sites and also colleagues in Technical Department of Shell Chemicals UK Limited who provided the trials data.

REFERENCES

Attwood, P.J. (1978) The susceptibility of annual broad-leaved weeds to herbicides used in cereals. In : Weed Control Handbook, 2 Fryer, J.D. and Makepeace, R.J. (Eds.), 8th edition, Oxford : Blackwell Scientific Publications, pp 15-20.

Brown, J.G.; Uprichard, S.D. (1976) Control of problem weeds in cereals with 3,6-dichloropicolinic acid and mixtures with phenoxy herbicides. Proceedings 1976 British Crop Protection Conference - Weeds, 1, 119-125.

Gilchrist, A.J.; Page, J.N. (1976) Development of 3,6-dichloropicolinic acid + mecoprop mixtures for selective broad-leaf weed control in cereals in the U.K. Proceedings 1976 British Crop Protection Conference - Weeds, 1 127-134.

Luckhurst, R.J.; Allen, M.G.; O'Doherty, P.C. (1972) The use of cyanazine mixtures for weed control in cereals. Proceedings 11th British Weed Control Conference, 2, 698-708.

Tottman, D.R.; Makepeace, R.J. (1979) An explanation of the decimal code for growth stages of cereals with illustrations. Annals of Applied Biology, 93, 221-234.

DICAMBA - NEW FACTS FOR WINTER CEREALS

J E HUDSON, J N BARLOW

Velsicol Chemical Limited, Reading, Berks. RG3 2JH, England.

ABSTRACT

Dicamba was applied at up to 150 grams/ha during GS 30-33 in 48 crop tolerance trials in weed-free winter cereals, during 1984 and 1985.

Dicamba applied at GS 31, 32 or 33 (1984) and GS 30, 31 or 32 (1985) caused no visual symptoms of crop phytotoxicity. In 1984 a yield reduction occurred at one wheat site which received 150g dicamba/ha at GS 33.

Mixtures of dicamba and bromoxynil or ioxynil with mecoprop treatments caused a temporary scorch like the standard, and temporary prostration at a few sites. The treatments applied at GS 30, 31 and 32 did not reduce yields, except for the highest rate applied at GS 31 in 1984 at one wheat site. The double rate of the bromoxynil with ioxynil and mecoprop standard reduced the yield at one wheat site in 1985 where applied at GS 31 and GS 32. Application at GS 33 caused yield losses at some sites, particularly wheats (6 out of 10 sites) for all treatments including the ioxynil/bromoxynil/mecoprop standard.

The yield data from these trials show that 60-72g dicamba/ha can be used in current winter wheats and barleys at up to and including GS 31.

INTRODUCTION

In the United Kingdom dicamba is available in mixtures, mostly with phenoxy-alkanoic acid herbicides such as MCPA and mecoprop, for broadleaved weed control in cereals. These products have a restricted recommended time of application which ends just before one node is detectable on the main shoot, GS 31. (Tottman and Makepeace 1979).

During the early 1970's there were reports of damage and crop losses in commercial crops. These losses were associated with presumed late applications of cereal herbicides including dicamba-containing products. Subsequent investigations confirmed that applying dicamba, alone and in mixtures with phenoxy-alkanoic acid herbicides, during stem elongation at rates from 1.5 upto 8 times higher than those commercially recommended could reduce crop yields (Munro 1976, Tottman 1982).

Current winter cereal cultivars are sown much earlier than those grown in previous decades. Such early sown crops will have passed the recommended crop growth stages for applying current products based on dicamba when weed control treatments are made in the spring. These factors justified a trials programme in winter cereals with dicamba, alone and with partner herbicides, to establish crop tolerance thresholds during early stem elongation, GS 30-33.

MATERIALS AND METHODS

Dicamba was included in two series of crop tolerance trials programmes carried out in commercial crops of winter cereals during 1984 and 1985. All of the sites were "weed-free" after treatment the preceding autumn with a broad spectrum residual herbicide. The 1984 programme treatments were applied at GS 31, 32 or 33. The 1985 treatments were applied at GS 30, 31 or 32.

Dicamba : programme 1

1984 Treatments	Rate g a.i./ha dicamba	No. of trial sites w.wheat	No. of trial sites w.barley
VCL 100	30 - 150	3	3
1985 Treatments			
VCL 100	72 ; 144	11	11

Dicamba + partner herbicides : programme 2

1984 Treatments		Rate g a.i./ha dicamba	mecoprop	other*	No. of trial sites w.wheat	w.barley
VCL 200	(1)	72	1080	360	10	10
VCL 201 + "B"		60	1425	300		
	(2)	72	1425	360		
		84	1425	420		
	(3)	120	2850	600		
"A"	(4)	-	2016	504		
"B"xx		-	3192	-		
1985 Treatments						
VCL 201 + "B"	(5)	72	1710	360	11	11
	(6)	144	3420	720		
VCL 201 + "C"		72	200x	360		
		144	400x	720		
VCL 204 + "B"		72	1710	360		
"A"	(7)	-	2016	504		
	(8)	-	4032	1008		
"B"	(9)	-	3192	-		

*bromoxynil and/or ioxynil; x = fluroxypyr; xx = applied at GS 32
Figures in parentheses signify treatments in Figures 3, 4.

The standards were products "A" and "B", proprietary formulations recommended for use during GS 31; "C" was also recommended for application during early crop stem elongation.

Experimental method

The field trials were made using a randomized block layout with four replicates per treatment. The plot size was 10m x 2m. Treatments were applied through a van der Weij AZO sprayer with a 2m boom fitted with 5 Lurmark F 110 150 nozzles giving a flat fan spray. The spray volume was 250 l/ha at 300 kPa.

Crop phytotoxicity was assessed 7-14 days after each application. Crop vigour was assessed on a linear, 0-10, scale where 10 = untreated control, during early ripening of the crop.

Crop yields were obtained from 1.5m x 10m strips, giving 15m^2 total area/plot, using a Hege 125B Plot Combine. Thousand grain weight analyses and grains/ear counts were also taken for both winter cereals at some sites.

Varietal tolerance trials

Dicamba, as VCL 100, VCL 200 and VCL 201 + "B", was evaluated in 1984 (at GS 30;32) and in 1985 (GS 31) in a varietal tolerance trial in winter cereals. The application rates were as used in Programme 2 for each year.

RESULTS

Dicamba : programme 1

Crop tolerance

In winter barley (14 field trials; 2 varietal trials) no phytotoxic response was seen in 1984. Transient scorch symptoms were just detectable in 1985 following the application of 144 g dicamba/ha at GS 30 (3 out of 11 sites) and GS 32 (1 out of 11 sites).

For winter wheat (14 field trials; 2 varietal trials) no phytotoxic effect was observed in 1984 or 1985.

Crop yields

The winter barley and winter wheat crop yields are summarized in Figures 1 and 2 respectively.

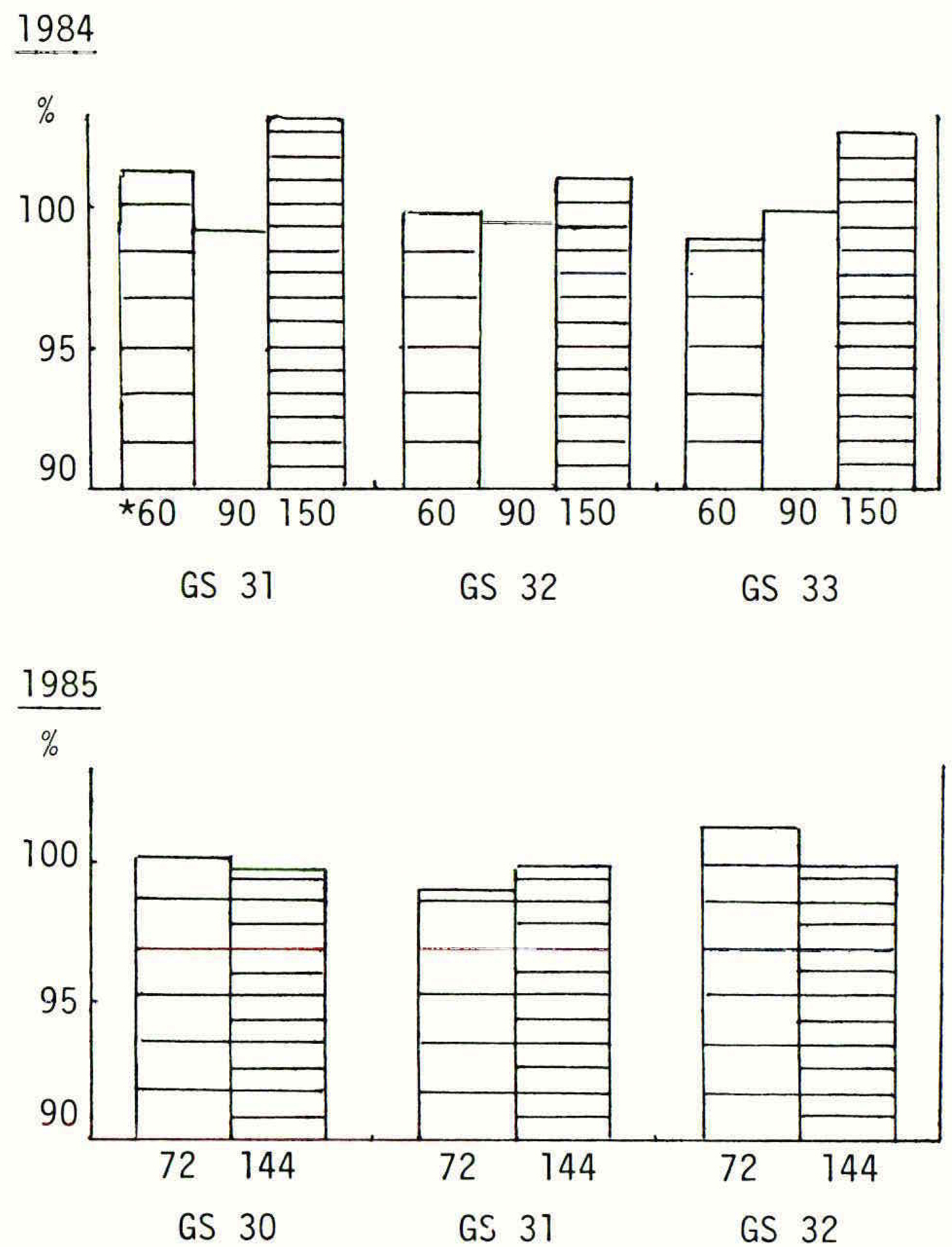
For winter barley there was no statistically significant yield reduction in either 1984 (3 sites) or 1985 (9 sites) at any rate, 30g upto 150g dicamba/ha, tested at GS 30, 31, 32 or 33.

In winter wheat (3 sites 1984; 8 sites 1985) there was a yield reduction (p=0.05) in 1984 at 1 site after applying 150g dicamba/ha at GS 33.

There was no statistically significant reduction in 1000 grain weights or in numbers of grain per ear for either winter cereal.

FIGURE 1

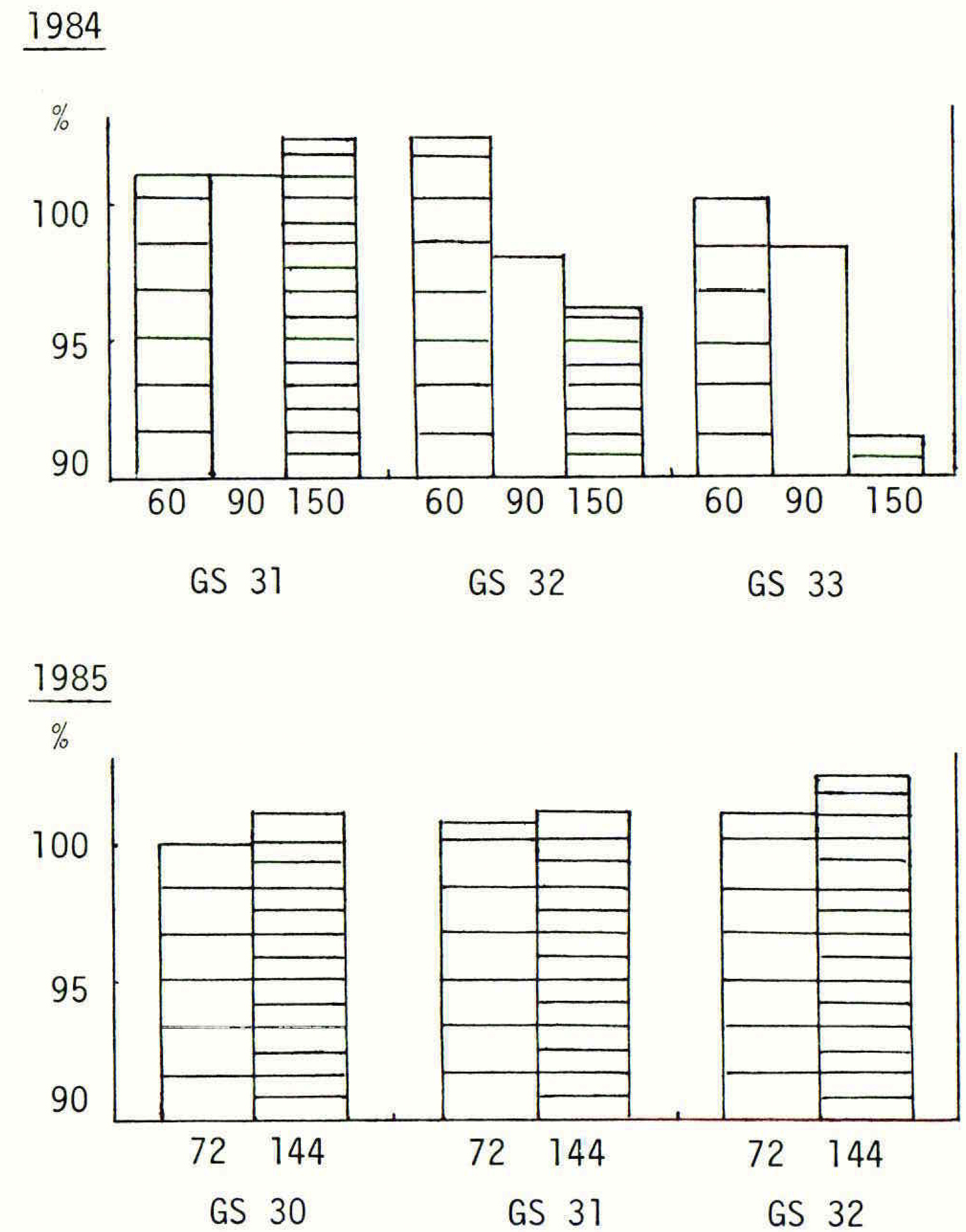
Dicamba % mean yields - winter barley



* g a.i./ha

FIGURE 2

Dicamba % mean yields - winter wheat



Dicamba + partner herbicides : programme 2

Crop tolerance

Transient crop scorch was recorded in both winter cereals at all growth stages for the reference products "A" and "B", at the same levels as for the dicamba plus bromoxynil and mecoprop (VCL 200; VCL 201 + "B") treatments. The tank mix treatments of VCL 201 with fluroxypyr, "C", induced even less scorch symptoms. No scorch was observed for dicamba plus ioxynil and mecoprop (VCL 204 + "B"). Temporary crop prostration was seen in 1984 after the applications of VCL 200 and VCL 201 + "B".

During 1984 in two winter barley sites retarded ripening with a slight reduction in ear length occurred after applications at GS 32 of "A", "B" and the highest rate of dicamba plus bromoxynil (VCL 201) with mecoprop. In winter wheat at one site blind glumes at the ear points were noted for all treatments applied at GS 33. No vigour reduction was observed at any site during 1985.

The 1984 and 1985 crop varietal tolerance data supported the field trial observations. Of the eight winter barleys, Gerbel was sensitive (temporary scorch and vigour check) to "A" and the highest rates of VCL 201 + mecoprop. Kanzler winter wheat was also checked temporarily by the highest rates of dicamba with bromoxynil plus mecoprop.

Crop yields

Figures 3 and 4 respectively contain the mean yield data for winter barley (1984, 8 sites; 1985, 9 sites) and winter wheat (1984, 10 sites; 1985, 8 sites).

Winter barley

At GS 30 none of the treatments had a significant effect on crop yields except for the double rate of "A" at one site in 1985. At GS 31 a yield reduction (p=0.05) occurred at one site in each year for the highest rate applied of dicamba plus bromoxynil with mecoprop. Both rates of "A" significantly reduced yields in one 1985 site.

At GS 32 there were yield reductions in one site out of eight (1984) for the highest rates of dicamba as VCL 201 plus mecoprop, and in one site out of nine sites (1985) for all of the treatments; but not with mecoprop or dicamba, applied by themselves. At GS 33 several of the dicamba treatments caused yield reductions (p=0.05) at one site.

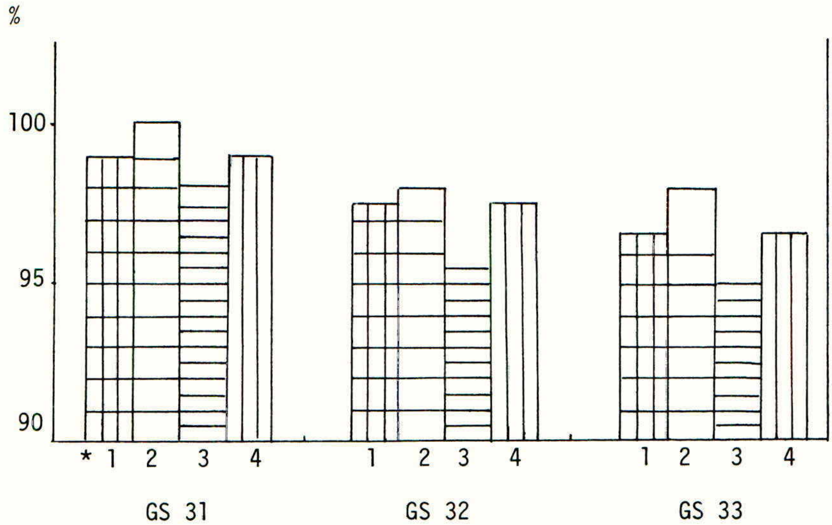
Winter wheat

No treatment affected crop yields when applied at GS 30. At GS 31 the highest rate of VCL 201 with mecoprop caused a yield reduction at one site in 1984. The double rate of "A" also significantly (p=0.05) reduced the yield at one site in 1985.

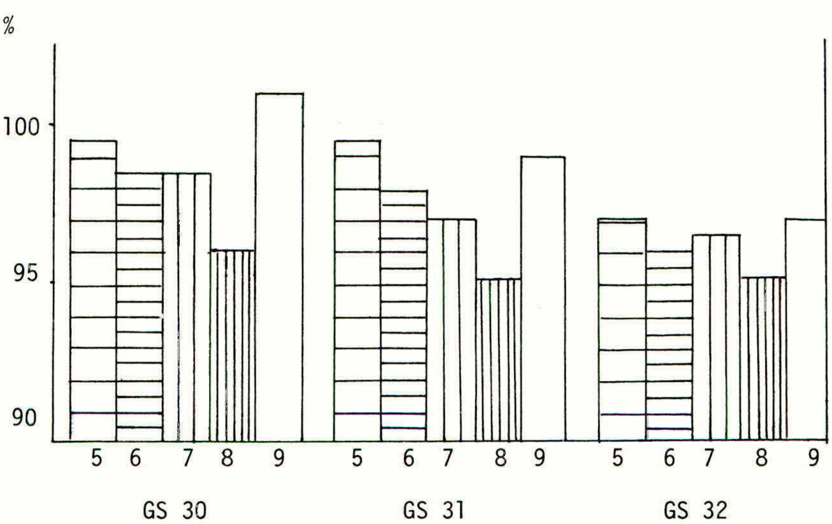
FIGURE 3

Dicamba + partner herbicides: % mean yields - winter barley

1984



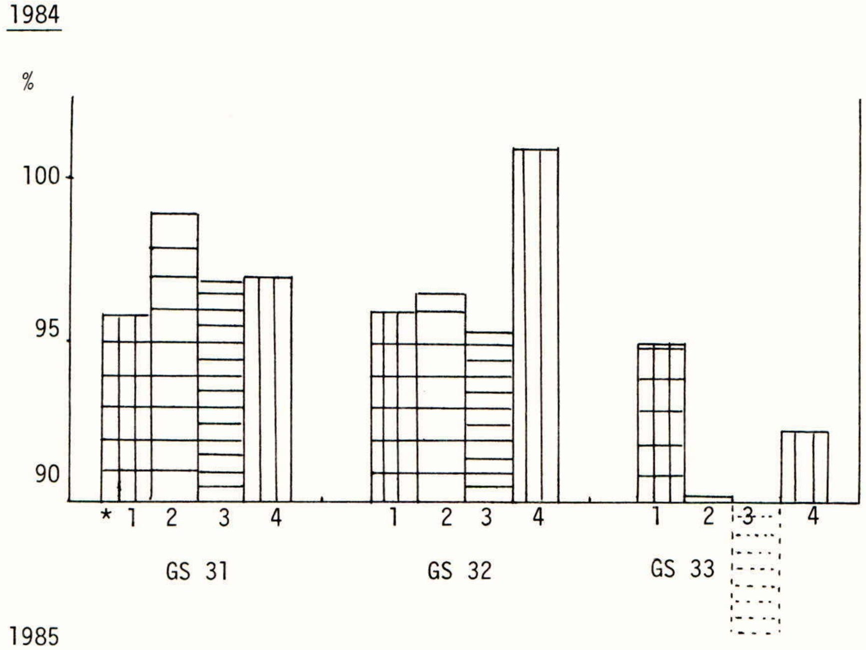
1985

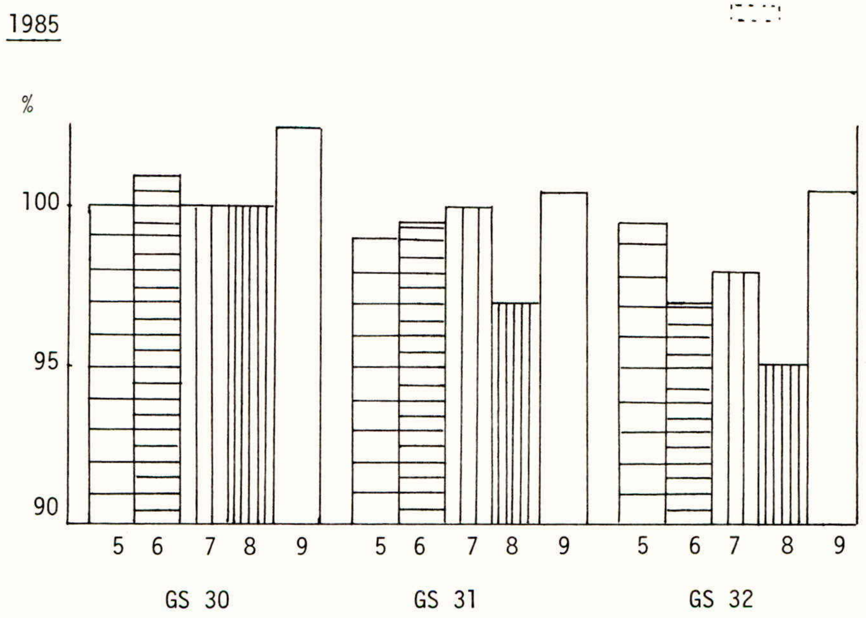


* Treatment details under Materials and Methods, Programme 2.

FIGURE 4

Dicamba + partner herbicides: % mean yields - winter wheat





* Treatment details under Materials and Methods, Programme 2.

For GS 32, in 1984 reduced yields occurred at two out of ten sites for VCL 201 plus mecoprop, and at one of these two sites for mecoprop. In 1985 the double rate of "A" caused significant yield losses at two out of eight sites. The single rate of "A" also reduced yields at one of these sites. At GS 33 both VCL 201 plus mecoprop and "A" reduced yields (p=0.05) at four out of ten sites.

DISCUSSION

Applying 30g upto 120g dicamba/ha had no measurable effect, either visual or on crop yield, when applied at GS 30-33 in winter barley and winter wheat. The only significant yield reduction (p=0.05) followed an application of 150g dicamba/ha at GS 33 in one winter wheat site in 1984.

60g and 72g dicamba/ha applied at GS 30 and GS 31 with bromoxynil and either mecoprop or fluroxypyr, or with ioxynil plus mecoprop, gave comparable yields to the reference products "A" and "B". Applying these treatments during GS 32 and GS 33 (not the optimum timings for broadleaved weed control) was more likely to depress crop yields even though significant reductions occurred at only one site each in 1984 and in 1985 for winter barley, and in two winter wheat sites in 1984.

Overall the results of the two year programme showed that 60-72g dicamba/ha was safe to use during GS 30 - GS 31 (one node detectable). The results support the development of new combinations for weed control in winter cereals using these low rates of dicamba with a contact herbicide such as ioxynil.

ACKNOWLEDGEMENTS

We are indebted to the farmers who provided the sites and to members of the Agricultural Development and Advisory Service (ADAS), Agricultural Chemicals Approval Scheme (ACAS), Agrisearch Field Development Ltd., the Weed Research Organisation (WRO) and colleagues for their guidance and encouragement.

REFERENCES

Munro, I.A. (1972) Late spraying of winter wheat. Proceedings 11th British Weed Control Conference, 717-721.

Tottman, D.R. (1982) The effects of broadleaved weed herbicides applied to cereal crops at different growth stages. Aspects of Applied Biology 1, 1982 Broad-leaved weeds and their control in cereals, 201-210.

Tottman, D.R., Makepeace, R.J. (1979) An explanation of the decimal code for the growth stages of cereals, with illustrations. Annals of Applied Biology 93, 221-234.