THE ECONOMIC OBJECTIVES OF WEED CONTROL IN CEREALS

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My first reaction on being invited to give this paper was of inner anguish: there have been so many papers and parts of papers on why farmers should control their weeds. At the 1972 conference a panel of 5 experts on cereals gave a co-ordinated series of papers on the subject. There have even been explanations of why farmers should not control weeds (in certain circumstances). Many of the papers are unsatisfactory: they are long on words and short on figures and facts. Perhaps herein lay a challenge. If the financial facts can be obtained let them be assembled and presented; if they do not exist, let a genuine attempt fail and thus demonstrate a gap in knowledge that should be rectified. And so it came about that the word 'economic' was written firmly into the title.

In this paper a study has been made of relevant publications of the past 10 years, and of earlier ones if important. All papers lacking numerical results translatable into money have been excluded, so as to ensure that all the conclusions are based on economic data. In order to make the calculations certain assumptions have been made as follows. All cereal is accorded an at-harvest price of £80 tonne except where stated. The costs of field operations are those provided in the February 1978 list of contractor prices provided by the National Association of Agricultural Contractors, less 10% for profit. Herbicide costs are those provided in the tables prepared by the Agricultural Development and Advisory Service (ADAS) for 1977/78.

With this background let us now consider the principal objectives of weed control in cereals, excluding aspects that cannot be quantified such as 'pride in a clean crop' and bearing in mind that, although they are here dealt with in isolation, in reality the benefits are often cumulative.

The Prevention of Weed Competition which Reduces Crop Yield

Here is a subject dear to the hearts of herbicide developers and farmers alike, and rightly so because it is in this respect that weeds hit most directly at a farmer's financial return. Past proceedings of this conference and many other publications are full of documented experiences of large yield increases in cereals resulting from weed control. There can be no doubt that weeds in sufficient number and of sufficient aggressiveness reduce the yield of cereals to a value that fully justifies current herbicide costs. If there are any who doubt this, let a single figure of £195/ha net return from weed control in winter wheat in 1978 illustrate the point (Wilson, 1978).

However to-day's central issue is much more complex. With progressive reductions in the aggressiveness of weed competition, at what point does the yield increase through weed control cease to justify expenditure on control? Were weed competition a simple and predictable effect it would be easy to link cost of control to value of increased cereal output, but competition is very variable.

It is possible to link herbicide cost to the value of grain, and this is done in Tables 1 and 2. The figures illustrate current differences in herbicide costs. Simple herbicides for the control of broad-leaved weeds are relatively cheap and necessitate yield increases of the order of 3% (inclusive of application) to cover the cost of their use. Such forms of weed control are probably justified as a routine, particularly if other objectives of weed control are also taken into account. However this argument holds good only so long as the herbicides do not themselves adversely affect crop growth and yield.

The grass herbicides are more expensive and therefore call for more careful ~~consideration.~~ On the basis of the ~~herbicides~~ listed in Table 1 the control of Avena sp. and/or Alopecurus myosuroides calls for yield increases of 6.6-11.2% in a 5 t/ha crop to do no more than cover direct costs of control. At what levels of the two weeds may removal of competition provide these increases?

Two figures commonly used by advisers are 55 A. myosuroides plants/m^2 and 12 Avena plants/m^2 above which control is justified (North, 1978). A distinction is drawn between high yielding crops (able to withstand competition) and low yielding (not so). Bowler (1973) constructed a graph showing a straight line relationship of yield increase to Avena panicles/m^2. Unfortunately the data do not provide a basis for prediction early in the life of the crop. Guillemenet (1972) in France related A. myosuroides plants/m^2 to yield loss (as %) showing that 20, 80 and 180 plants/m^2 gave 6, 12 and 17% loss of winter wheat. However Chancellor and Peters (1972) and Moss (1978) have shown over what an extended period after crop emergence may the two weeds appear; and how different is the aggressiveness of Avena according to its growth stage relative to the crop. Dew (1973), in Canada, has suggested that actual yield loss is a function of the square root of weed population, and that percentage loss is a function of weed density and emergence relative to the crop. In some 80 experiments on Avena in spring barley Wilson (1978) failed to establish a direct relationship between early weed population and subsequent yield. Baldwin (1978) reporting 106 experiments carried out by the Agricultural Development and Advisory Service confirmed North's figure for threshold Avena population but rejected that for A. myosuroides, he also listed two additional factors affecting yield increase; earliness and completeness of control.

Thus the factors known to affect level of yield response are: general level of crop vigour, weed population, weed stage of growth relative to crop, time of herbicide application, degree of control obtained. It must be admitted that our present state of knowledge does not permit a reliable prediction of the onset and consequences of grass weed competition. This gap in our knowledge is equally wide in respect of common broad-leaved weeds.

A Clean Trouble-Free Harvest

In the days of binders weeds hindered harvesting little except in the discomfort of the workers. But combine harvesting has become an increasingly complex and carefully-balanced operation. A typical situation to-day might be two combines and four men confronting 400 ha of standing corn from which they hope to extract 2,400 tonnes of grain in 15 working days. The ideal situation is of every field with crop standing and not a weed in sight. Why is it that farmers clearly attach so much importance to a clean trouble-free harvest?

Weeds alter the ratio of total matter to grain going into the combine. They may also, if green, alter the moisture content and the consistency of the bulk sample being processed. If the crop is laid and contains green weeds there may be difficulty in ensuring collection on the combine table and regular feeding of the drum.

When starting to harvest a crop, the driver sets the various adjustments on the combine as best he can and moves forward at a speed consistent with a regular and optimal throughput of material. 'Optimal' means as fast as possible without blockage and without undue threshing losses (Figure 1) because the faster the speed the greater the area covered in a day's work. Losses due to weeds stem from two happenings:

1. Incomplete separation in the combine leading to grain being shed to the ground.

2. A reduction in speed of forward movement leading to reduced area harvested in a day's work.

Weed infestations are usually irregular and so therefore is the total plant matter per m^2 on offer to the combine. A combine being operated efficiently at a low level of loss may suddenly suffer increased throughput which puts the process onto a higher plane of threshing loss. In Figure 1 the results of farm combine harvesters under field test by ADAS have been calculated at 1978 values. Once the bulk input is such as to place the operation on the steep part of the curve, the loss appears to be £7-9/ha for every additional 1 t/hour of bulk input.

The presence of green weed material would add a further loss which is difficult to quantify. Wieneke and Caspers (1974) under experimental conditions increased the loss of wheat from 0.3% to 1.2% and of oats by 3% after adding clover and grass to cereal samples before threshing. Segler and Wieneke (1961) found that increasing the presence of green material in wheat and oats from 0 to 45% by weight, increased the total grain losses from 0.68 to 6.87%, and incidentally the power requirement of the drum from 3.1 to 19.5 h.p. A loss of 7% in a 5 t/ha crop would amount to £28/ha.

But, of course, no sensible driver would incur separation losses by continuing at speed when entering a green weed infested area. By slowing down and adjusting cutting height, the total throughput would be reduced towards a small separation loss. But in so doing a different form of loss would occur. Although the crop to be retrieved can be regarded as so many tonnes per hectare, combine costs are usually on a time basis. Thus the penalty of reduced speed is an increased cost per tonne of grain harvested or per hectare covered. The relationship is linear for any one crop: a reduction in speed from 10 kph to 7.5 kph (25%) would increase the cost per tonne from £9.8 to £12.2 in a 5 t/ha crop at an average combine cost of £49/ha. Farmers would regard this increase as significant and worth avoiding. Even where the nature of the total material is unlikely to reduce combine speed as in Table 3, the consequence of weed competition in reducing the ratio of grain to total material may be an increased cost of combining of £2.50 per tonne of grain.

This financial approach allows a distinction between certain types of weed in terms of their consequences.

Weeds such as Avena, A. myosuroides and many annual broad-leaved weeds compete with the crop, reducing the yield of grain (and probably of straw also) and are largely ripe and desiccated by harvest. The main damage these weeds do is in reducing the grain per unit area. They probably do not increase substantially the total weight of matter per unit area; so combine speed is maintained and increases in combining costs are modest (Table 3). The exception to this conclusion may be with winter barley in a wet July when Avena may still be green.

Weeds such as Sonchus arvensis, Polygonum amphibium, Convolvulus arvensis and Cirsium arvense are late emerging and do not therefore reduce the grain or straw per unit area; but by their presence (often green) they substantially add to harvesting difficulty and loss.

The really damaging weeds are those which compete with the crop reducing yield <u>and</u> maintain a bulky green presence causing harvesting losses particularly in wet years. Which are these weeds? Perhaps <u>Agropyron repens</u>, <u>Galium aparine</u>, <u>Stellaria media</u>, <u>Chrysanthemum segetum</u> and <u>Matricaria</u> sp.: we don't know because this is a subject that has not been researched.

Returning to a more general consideration of harvesting. A farmer at the point of harvest has already incurred variable costs of ca. £100/ha plus overheads in getting the crop to this point (Table 6), he has grain to the value of £350-400/ha at risk. He is about to engage in an operation costing about £49/ha. What insurance premium should he have been prepared to pay just to ensure a weed-free harvest? Surely £2 per tonne of grain is reasonable, but is £3 or £4?

A Clean Sample of Grain

A clean sample of grain for malting should carry a premium over a contaminated one but it does not always do so appreciably. At the present time maltsters are more concerned to get a correct quality of barley even if it contains some <u>Avena</u> than with a sample free of this weed. Thus there are not necessarily substantial premiums to be had for clean malting barley. However in a year of good quality grain, the clean sample will sell for malting and the dirty sample will not.

The seed trade offers a premium of £10-£20/t for clean acceptable samples which might be worth £75/ha in a 5 t/ha crop. In a seed growing situation what the farmer risks by weed contamination is the loss of the premium together with a non-recoupment of the extra cost of seed that he purchased (up to £55/t of seed). The consolidated loss could be £85/ha. The farm experiences in Table 4 illustrate what can happen when a crop is rejected for seed or priced down because of weeds; in field 3 about half the loss is due to weeds. The seed merchant also has much at stake. If he rejects the crop he may be short of his supply of that variety; if he accepts a contaminated sample he will lose a proportion of the crop seed during cleaning to a variable extent up to 50% of the sample in the case of <u>Avena</u> sp. and volunteer cereals (Pertwee, 1972).

It is not usually possible for a farmer to sell grain for feed with more than 3% admixture without incurring a penalty for cleaning by the merchant. The penalty is twofold; the cost of cleaning and the adjustment for loss of weight caused by removing the contaminants.

A recorded experience in a heavily contaminated crop of winter barley is shown in Table 5. Not only was the yield reduced but the sample on the unsprayed area contained much <u>Avena</u>: the effect of these two was cumulative, the purchaser would have taken into account the cost of cleaning and the reduction in weight due to removal of <u>Avena</u>, when offering a price. For a similar combine yield around 5 t/ha the cost of cleaning alone would be about £40/ha, nearly enough to pay for the herbicides. But when the gross yield reduction due to weed competition, the loss in weight in cleaning and the cleaning charge are taken into account the financial difference in favour of weed control was about £196/ha, a figure that dwarfs the cost of weed control.

It appears that merchants' penalties for having to clean grain may be a major factor in weed control, particularly with the increasing sowing of winter barley with its tendency to contain more weed seed than cereals harvested later.

The Prevention of Crop Loss due to Diseases Associated with Weeds

Weeds as alternate hosts to pests and diseases are a subject much commented on, but in respect of cereals there is little hard fact. The British Weed Control Handbook (1977) makes reference to Agropyron repens being associated with take-all (Gaeumannomyces graminis), and Alopecurus myosuroides with Claviceps purpurea, but concludes that there is often little evidence on which to assess the practical importance of weeds in this connection.

A revealing experience was reported by Hughes (1974). In the Arundel area of Sussex in 1966 a disastrous harvest of spring barley (yield 2.5 t/ha) was considered to have been caused by mildew and brown rust (Puccinia hordei) having been overwintered on volunteer barleys growing as weeds. A co-ordinated programme on some 1200 ha to prevent the sowing of winter barley and to ensure the killing of weed barley caused a major reduction in disease severity during 1967-70, and yields were reported as having risen to 5 t/ha in 1974.

Were the increased yield to the value of £200/ha at 1978 prices all attributable to the killing of volunteer barley plants, the cost of the cultivations and/or chemicals to ensure good hygiene would be dwarfed by the increased value of grain. But in reality other facets of barley production would have improved during the 7 year interval, including the use of fungicides on barley.

Hughes also described a serious outbreak of yellow rust, Puccinia striiformis, in winter wheat during 1972. A survey by pathologists associated the outbreak with volunteer wheat plants present in autumn 1971 and attributed a yield loss of 0.88 t/ha to infected crops. At 1978 values this loss would be equivalent to £70/ha, a sum substantially greater than the cost of stubble cultivation (£8/ha) or the use of paraquat to kill the volunteers.

A major objective of weed control is the avoidance of avoidable risks. The financial losses in these two experiences support strongly the use of cultivation and/or chemicals to eliminate volunteer cereal plants.

Freedom to Grow the Most Profitable Crops

Agriculture has moved a very long way from the days of 'cleaning' and 'fouling' crops which were balanced by crop rotation in which weed control was a central object. Since cereals were the fouling crops a major success of chemical weed control has been in setting them free of this stigma. The consequence of nearly 30 years of herbicide development has been to allow farmers to grow ever more cereals thereby achieving the high crop performance of specialisation and the low overheads of scale.

In recent years the combined effects of non-ploughing and herbicides coupled with a price differential in favour of wheat, have encouraged an increasing proportion of autumn wheat at the expense of spring barley. In the past two years winter barley has increased markedly at the expense of spring barley, and this trend is expected to continue. It is obvious that none of this could have happened without chemical weed control, but what may not be so obvious is whether the expected increase in financial returns will more than offset the increased costs of weed control.

Spring barley has come to be a cleaning crop for winter wheat in respect of autumn germinating weeds such as A. myosuroides, Poa trivialis, Galium aparine, Veronica persica, Stellaria media and even to some extent for A. fatua. Thus a switch from spring to autumn sowing must sooner or later incur an increased cost of herbicides for grass weed control. There is a further point that cereals sown early in the autumn do not form a competitive canopy for 5-6 months so there is a probability of several herbicide applications.

In Table 6 are presented financial results from two authoritative sources. They are not intended to be comparable since ICI figures are for high standard farms including no doubt many wheat crops after grass with low costs of weed control whereas the ADAS figures are an estimate of average situations including second and subsequent wheats. They do not reflect the very favourable yields of winter wheat and barley and the modest yields of spring barley obtained over most of England in 1978. The ADAS figures for barley contain an addition of £32.50/ha for the value of straw which may not be gained by the farmer who burns.

It is interesting that ADAS suggest a lower gross margin for winter wheat and barley than spring barley (£214 and 229 v. 254) whereas ICI shows wheat to have advantage over barley (£342 v. 228 and 270). However, of more interest is the difference in spray costs of which most is for herbicides, ranging from £14 to £68/ha. If the ADAS figures for sprays are attributed to the ICI budgets the gross margins then become £298/ha for winter wheat, £251/ha for winter barley and £266/ha for spring barley; the differences are small and not in favour of winter barley. However the 1978 budgets may appear more favourable to winter barley.

A Midlands cereal farmer has reported crop protection costs of £88/ha (of which £62 was for grass herbicides) incurred in 1978 winter wheat. A merchant has advocated a herbicide programme for 1978 winter wheat which has been calculated to cost £78/ha (of which £67 was for grass herbicides). Compared with these figures the ADAS cost of all sprays at £68/ha appears modest.

Can such levels of herbicide expenditure be justified in winter cereals? Here is an area of debate. A farmer who opts for a particular cereal system should carry it through carefully and efficiently if he is to succeed, thereafter he may look for economy of input. The conclusion drawn by ICI was that the results justified the means: the farmers who achieved the highest yields had the highest variable costs per hectare (including herbicides) yet their variable costs per tonne were lower than farmers with low yields. Here surely is the key: in a successful high yielding system today's herbicide costs can be well justified; but low yields mean low returns and up to a 30% increase in variable costs per tonne of grain according to ICI.

The late Harry Truman was reported to have said "If you can't stand the heat in the kitchen, get out". This might apply to some farmers who can't achieve a high yield of winter cereal for one reason or another; spring barley with its low spray costs might be safer. On the other hand, should it not be the role of technologists to "reduce the heat in the kitchen" by evolving cheaper weed control in winter cereals?

Conclusions

The current value of the 1978 cereal crop in the United Kingdom is about £1400m. Of the various inputs to achieve this return farmers have probably applied £40-£50m worth of herbicides as well as using many indirect methods of weed control. The annual sums of money are so large that it might be expected that the economic justifications would have been carefully evaluated on a national and farm basis. The need for such evaluation was recognised by the Cereals Committee of the Joint Consultative Organisation which recorded that "Studies are needed of the objectives, costs and benefits of weed control systems for cereal crops ... The quantification of these benefits will help in the assessment of the cost that it is worth incurring to achieve the desired degree of weed control" (MAFF, 1977). Although the Cereals Committee awarded priority A to the subject, the Arable Crops and Forage Board did not include it in its major recommendations.

A search of the published literature of the past 10 years has revealed no systematic attempt to evaluate the objectives in factual and financial terms. In default of this the evidence is fragmented and indirect. Such as it is I offer the following conclusions.

1. The most damaging effect of weeds is in the reduction of crop yield. After 30 years of chemical weed control many field populations are much reduced. There is inadequate information on threshold levels of different weeds that justify expenditure on chemicals.

2. The designers of combine harvesters must have quantified the effects of weeds on combine performance. This information is not readily available to agronomists. Since certain types of weeds are more damaging than others, there is a need for weed specialists and engineers to get together to clarify the situation.

3. In respect of seed and feed grain the cleanliness of the sample is of considerable importance to farmers and failure to achieve merchants' standards now carries a heavy financial penalty. Winter barley, because of its early harvest, is particularly prone to contamination. In view of the major increase of this crop, farmers should be alerted to the need for weed control.

4. The increasing trend of 'reduced cultivation and early autumn sowing of cereals' presents a challenge to both farmers and herbicide technologists: can the former obtain yields high enough to pay for crop protection chemicals, and can the latter reduce the costs of weed control to an acceptable level for the average producer?

A key relationship is the cost of grass herbicides and the value of a tonne of wheat or barley. A rise in the former relative to the latter could place winter cereal growing in difficulty on other than the best cereal soils. Technical progress in reducing the former relative to the latter would probably result in even more winter cereals with more herbicide use in total.

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Table 1

Approximate herbicide costs and equivalent grain value 1977/78

Typical costs of some herbicides purchased for 1977/78 cereal crop

	Cost £/ha	Equiv wt of grain t/ha	% increase in 5 t/ha crop
Barban	20.4	0.3	5
Benzoylprop-ethyl	34.7	0.4	9
Chlortoluron	39.3	0.5	10
Difenzoquat	24.1	0.3	6
2,4-DP	6.0	0.1	2
Isoproturon	39.3	0.5	10
Mecoprop	5.2	0.1	1
Methabenzthiazuron	28.6	0.4	7
Cost of application	5.7	0.1	1

Table 2

Value of crop and losses

Crop yield t/ha	Value (£)	Value (£) of loss 1	5	10	20	40%
8	640	6.4	32	64	128	256
7	560	5.6	28	56	112	224
6	480	4.8	24	48	96	192
5	400	4.0	20	40	80	160
4	320	3.2	16	32	64	128
3	240	2.4	12	24	48	96

Table 3

Analysis of material for combine harvesting

Mean values from 51 *Avena* sp expts (Wilson & Peters 1978)

		Crop clean	Crop + wild-oat
barley grain	t/ha	4.4	3.6
" " + straw	t/ha	8.2	7.0
wild-oat " + straw	t/ha	-	1.3
total combine material	t/ha	8.2	8.3
ratio barley grain : total bulk		0.54	0.43
combining cost	£/ha	49	49
" " , barley	£/t	11.1	13.6

Table 4

Experiences in 1978 of growing cereal seeds contaminated by G. aparine (Hart, 1978)

		Field 1	Field 2	Field 3
crop		oats	wheat	wheat
area	ha	12	14	12
yield as grown	t	58	70	75
extra cost of C1 seed	£	112	88	112
premium due to farmer	£	957	700	1125
purity: Nos weeds/2 kg		92	30	16
crop accepted/rejected		R	R	A*
total loss	£	1069	788	187
loss/ha	£	82	52	14

* Accepted but premium reduced by £1/t

Table 5

Effect of Avena sp contamination on value of winter barley*

		Crop sprayed	Crop not sprayed
combined yield	t/ha	6.1	5.1
containing Avena sp	%	1.6	17.6
clean barley > 2 mm	t/ha	5.5	3.4
value of barley > 2 mm at £74/t	£/ha	407	252
cost of cleaning	£/ha	-	41
loss due to weed contamination	£/ha	-	196

* A crop cv. Malta grown in Oxon during 1973/74; calculations are based on information supplied by a local corn merchant

Table 6

Cereal production budgets 1977 at 1978 values

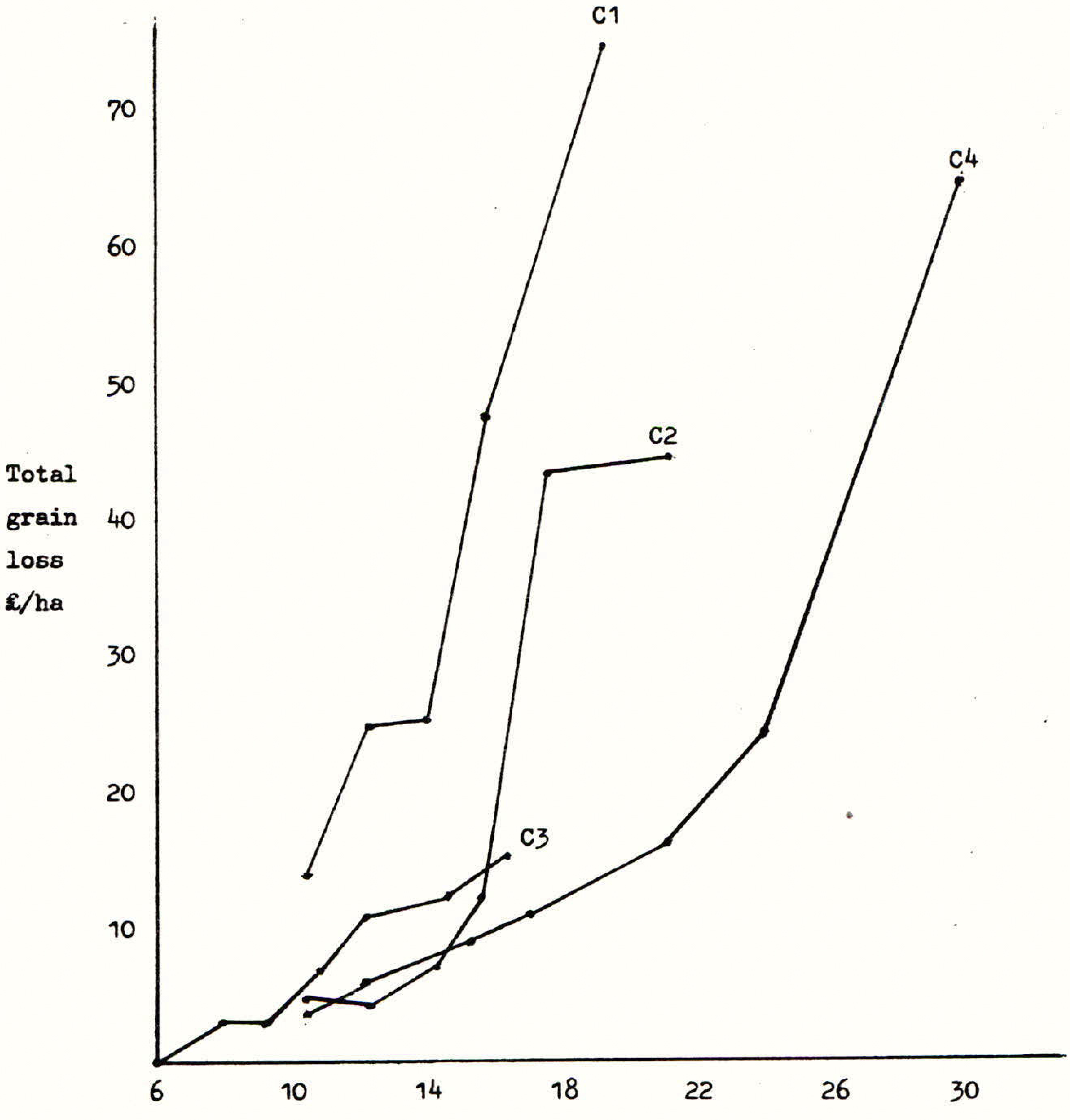
		W. wheat ICI*	W. wheat ADAS**	W. barley ICI	W. barley ADAS	S. barley ICI	S. barley ADAS
yield	t/ha	5.2	4.4	4.6	4.2	4.5	4.0
crop output	£/ha	434	352	370	351	346	336
variable costs	£/ha	91	138	83	122	76	83
sprays	£/ha	24	68	21	58	14	18
gross margin	£/ha	342	214	288	229	270	254

* Imperial Chemical Industries Ltd. (1978)

** Agricultural Development and Advisory Service (1978)

Figure 1

Effect of throughput on grain loss in 4 combines



NOTES

Proceedings 1978 British Crop Protection Conference - Weeds

CHEMICAL CONTROL OF AVENA FATUA IN SPRING BARLEY

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Summary In eight trials, five herbicides, barban, diclofop-methyl, difenzoquat, flamprop-isopropyl and L-flamprop-isopropyl were compared in the harvest years 1977 and 1978 using full and reduced rates, alone and in sequence. Control of A. fatua and crop yield (1978 only) were assessed.

All herbicides used at their recommended rates gave satisfactory control of A. fatua, with variable 'windows' of activity from narrow, in the case of diclofop-methyl, to wide with difenzoquat. Low yield responses leading to financial loss were common except at one site where A. fatua populations were very high (294/m^2). Crop damage was observed, especially where the above two herbicides were used.

The sequences were effective but gave improved control of A. fatua only when compared with barban and diclofop-methyl alone, and improved yield response only in the case of barban. It would be hard to justify their preference over the best single application of difenzoquat or L-flamprop-isopropyl.

Except at very high infestations, the expense of controlling A. fatua in competitive spring barley crops must be considered as an insurance premium for a long term policy of eradication or reduction of A. fatua.

INTRODUCTION

The series of trials described here continues the programme carried out by ADAS Eastern Region Agronomy Department, to provide information on the relative effectiveness of herbicides for the control of Avena fatua in spring barley (Baldwin J. H. and Finch R. J. 1974, 1976). In 1977 the trials concentrated on finding the optimum timing for a range of herbicides, and to assess the importance of time of removal of A. fatua on crop yield. In 1978, a number of sequences of herbicides at reduced rates, but applied at or near their respective timings were compared. The possibility of decreasing the risk of crop damage while maintaining the efficiency of A. fatua control stimulated an interest in such sequences.

METHOD AND MATERIALS

All the experiments were on commercial crops where naturally occurring populations of *A. fatua* were expected.

Herbicide treatments for 1977 and 1978 are shown in Table 1. Site details, application dates, stages of crop and weed are shown in Table 2. A randomised block design was used with three replications. Plot size was 3m x 10m and all treatments were applied using a modified van de Weij sprayer with Allman '00' jets. Application rates in 1977 and 1978 were 225 l/ha at 2.21 bar for all treatments except barban which was applied at 168l/ha at 2.76 bar in both years, and diclofop-methyl applied at 250 l/ha at 2.5 bar in 1978 only.

Control of *A. fatua* was assessed in July or August by removing panicles from a number of quadrats in each plot, and recording numbers and dry weights. Crop yields were assessed by a sample harvest technique. Statistical analyses of the results had not been completed at the time of publication, but may be obtained at a later date from the authors.

Table 1

Treatments

1977

Time of application (Zadoks)

	Crop	*A. fatua*
A	12–14	11–14, 22
B	13–15, 23–24	12–15, 22
C	15, 23, 30	14–16, 22–25
D	24, 30–31	12–16, 22–25, 30
E	37–41	36–39

1978

Time of application (Zadoks)

	Crop	*A. fatua*
A	12 or beyond	11–12
B	Before 30	13–14, largest 21
C	Early 30, before 31	Up to 30
D	31	30 or beyond
	-	-

1977

Herbicide a.i.kg/ha (Time of app.in brackets)

	Herbicide	a.i. kg/ha	Time
1	barban	0.34	(A or B)
2	diclofop-methyl	1.26	(A or B)
3	difenzoquat	1.00	(B,C,D or E)
4	flamprop-isopropyl	1.00	(C, D or E)
5	L-flamprop-isopropyl	0.60	(C, D or E)
6	untreated control		

1978

Herbicide a.i. kg/ha (Time of application in brackets)

	Herbicide	a.i. kg/ha	Time	Herbicide	a.i. kg/ha	Time
1	barban	0.34	(A)			
2	barban	0.17	(A)			
3	barban	0.17	(A)	difenzoquat	0.50	(C)
4	barban	0.17	(A)	L-flamprop-isopropyl	0.40	(D)
5	diclofop-methyl	1.08	(A)			
6	diclofop-methyl	1.08	(B)			
7	diclofop-methyl	0.54	(A)	difenzoquat	0.50	(C)
8	diclofop-methyl	0.54	(A)	L-flamprop-isopropyl	0.40	(D)
9	difenzoquat	1.00	(B)			
10	difenzoquat	1.00	(C)			
11	difenzoquat	1.00	(D)			
12	difenzoquat	0.50	(C)			
13	difenzoquat	0.50	(B)	difenzoquat	0.50	(D)
14	L-flamprop-isopropyl	0.60	(C)			
15	L-flamprop-isopropyl	0.60	(D)			
16	L-flamprop-isopropyl	0.40	(D)			
17	untreated control					

Table 2

Site details

	1977			1978				
Site	1	2	3	4	5	6	7	8
Soil texture	CL	CL	ZyCL	ZyCL	SL	SC	FSL	ZyL
Variety	Mazurka	Maris Mink	Maris Mink	Tern	Tern	Aramir	Porthos	Athos
Drilling date	14 April	12 April	8 April	15 April	25 April	16 March	20 April	3 April
Date of herbicide application and growth stages (Zadoks) of crop and weed								
A	-	10 May	9 May	11 May	3 May	3 May	22 May	19 May
Crop				13-14	12	13-14,22-23	13-16,21-24	13-14
A.fatua				11-14	11-12	11-13,22	11-14	11-13
B	23 May	23 May	19 May	31 May	25 May	26 May	31 May	1 June
Crop				30-31	13-15	23-25	14-15,20-23	14-16,22-24
A.fatua				12-16,20-25	11-16	12-16,21-23	12-15,20-23	11-15,23
C	31 May	31 May	26 May	6 June	1 June	1 June	6 June	6 June
Crop				30-32	16,21-25	31-32	30-31	30-31
A.fatua				13-18,21-28	12-16,22	12-16,21-24,31	13-30	12-18,25
D	10 June	9 June	1 June	12 June	12 June	6 June	13 June	13 June
Crop				33-37	31-32	37	32-37	32-37
A.fatua				22-26,32	13-32	36	15,22-32	12-32
E	24 June	24 June	23 June	-	-	-	-	-
Crop								
A.fatua								

Table 3

Control of Avena fatua (%) 1977

	Treatment	Site 1	2	3
	Control Dry wt. panicle g/m^2	81	30	45
A	9-10 May, Crop 12-14, A.fatua 11-14,22			
	barban	-	75	84
	diclofop-methyl	-	97	96
B	19-23 May Crop 13-17, 23-24 A.fatua 12-15,22			
	barban	-	39	87
	diclofop-methyl	66	65	90
	difenzoquat	100	100	100
C	26-31 May Crop 15,23-30 A.fatua 14-16,22-25			
	difenzoquat	97	-	100
	flamprop-isopropyl	97	89	85
	L-flamprop-isopropyl	100	95	98
D	1-10 June Crop 24, 30-31, A.fatua 12-16, 22-25,30			
	difenzoquat	-	54	100
	flamprop-isopropyl	88	88	89
	L-flamprop-isopropyl	93	89	97
E	23-24 June Crop 37-41, A.fatua 36-39			
	difenzoquat	99	83	99
	flamprop-isopropyl	75	93	92
	L-flamprop-isopropyl	93	96	98

Table 4

Grain yield as percentage of control yield (15% moisture content) 1978

	Herbicide	Time of application	Site 4	5	6	7	8	Mean	*Margin £/ha over herbicide
	Control	t/ha	4.50	3.05	5.35	3.13	3.66	3.94	
1	barban	A	120	116	93	87	97	100	-20
2	barban ½	A	108	115	96	113	96	104	+ 1
3	barban ½ difenzoquat ½	A C	118	132	93	111	100	109	+ 3
4	barban ½ L-flamprop-isopropyl ⅔	A D	102	136	100	116	106	110	+ 4
5	diclofop-methyl	A	110	123	100	101	105	107	- 5
6	diclofop-methyl	B	95	124	93	112	101	103	-16
7	diclofop-methyl ½ difenzoquat ½	A C	84	145	105	101	104	106	- 8
8	diclofop-methyl ½ L-flamprop-isopropyl ⅔	A D	103	110	104	97	112	105	-16
9	difenzoquat	B	105	127	98	95	115	107	- 5
10	difenzoquat	C	97	133	89	95	105	102	-18
11	difenzoquat	D	98	120	91	91	107	100	-24
12	difenzoquat ½	C	100	123	94	108	96	102	- 6
13	difenzoquat ½ difenzoquat ½	B D	100	141	93	109	108	107	- 5
14	L-flamprop-isopropyl	C	104	132	107	113	116	113	+ 9
15	L-flamprop-isopropyl	D	85	143	99	112	105	106	-11
16	L-flamprop-isopropyl ⅔	D	96	129	88	111	101	102	-12

* Barley (feed) priced at £70/tonne U.K. weighted ave. Aug. 1977 to July 1978

Table 5

Control of Avena fatua (%) 1978

Herbicide	Time of application	Site 4	Site 5	Site 6	Site 7	Site 8	Mean
1 barban	A	49	85	89	40	95	75
2 barban ½	A	30	32	74	56	91	44
3 barban ½	A						
difenzoquat ½	C	89	96	98	95	98	96
4 barban ½	A						
L-flamprop-isopropyl ⅔	D	70	84	86	89	97	86
5 diclofop-methyl	A	88	85	98	87	96	87
6 diclofop-methyl	B	84	77	91	97	86	83
7 diclofop-methyl ½	A						
difenzoquat ½	C	97	95	85	73	92	89
8 diclofop-methyl ½	A						
L-flamprop-isopropyl ⅔	D	39	92	90	96	96	92
9 difenzoquat	B	80	99	98	99	100	99
10 difenzoquat	C	59	98	95	94	98	97
11 difenzoquat	D	78	87	84	97	94	89
12 difenzoquat ½	C	55	96	67	42	96	81
13 difenzoquat ½	B						
difenzoquat ½	D	77	99	96	95	99	97
14 L-flamprop-isopropyl	C	44	99	94	86	92	95
15 L-flamprop-isopropyl	D	33	81	69	88	95	82
16 L-flamprop-isopropyl ⅔	D	12	74	88	82	76	77
Control Dry wt panicle g/m^2		2.2	170.8	18.9	62.6	17.8	54.4
No/m^2		5	294	18	66	29	82

DISCUSSION

This trial series, had slightly different objectives in the two years. In 1977 at three sites, the efficiency of the principal herbicides were compared at various timings. Yields were not measured.

The 1977 trials showed the necessity of applying barban or diclofop-methyl at the one or two leaf stage of crop or weed for optimum control. Results were less reliable if spraying was delayed. In contrast difenzoquat showed a wider 'window' of activity and was effective over the whole range of its recommended use, but its poor rainfastness was the suspected cause of a poor result at one site. The new isomer L-flamprop-isopropyl was very effective and superior to flamprop-isopropyl, especially when sprayed at the emergence of the crop flag-leaf.

The 1977 experiments were limited by the lack of yield data. It was impossible to discern the balance between the yield advantage from controlling A. fatua and the possible detrimental effect of the transitory crop scorch, which occurred with some treatments.

In 1978, therefore, the main herbicides were applied at their optimum timings, but different sequences using reduced rates were compared, to see if extra crop safety could be achieved without sacrificing A. fatua control. Crop yields were measured.

Despite the normally rapid growth of barley in the spring, at least fifteen days elapsed between the two sprays of the closest sequence. Although a slow, cold spring slowed the early growth of the crop in 1978, it seems that sequential spraying would be practically feasible in the spring barley crop.

Yield responses, and therefore margin over cost of chemical, were not impressive, despite high levels of A. fatua control. This was true in populations from 5 to 66 plants/m^2, but at one site (5) where the weed population was c. 300 plants/m^2, yield responses were high, ranging from 115 to 145 per cent of a low control yield. These observations suggest that crop damage may outweigh the advantages of removing A. fatua competition except at very high infestations.

Damage symptoms occurred at all sites with full rates of difenzoquat and diclofop-methyl and at two sites with full rate barban. These effects were not reflected consistently in yield differences. Difenzoquat, however, at high levels of control tended to give yield responses similar to or smaller than those with L-flamprop-isopropyl (no damage symptoms observed for similar or lower levels of A. fatua control).

The barban sequences were the most successful, giving improved A. fatua control and yield response compared with a single application of full or half rate barban, which was unreliable. Poor results at one site each for the difenzoquat and L-flamprop-isopropyl sequences, affected the overall means of these treatments. Because of the relative cheapness of barban, the margins of those sequences using it were positive, if small.

The same weed control improvements occurred with the difenzoquat or L-flamprop-isopropyl sequences with diclofop-methyl, which showed reduced activity when applied after commencement of tillering of the weed. All yield responses, however, were low and margins generally negative; perhaps an indication of an overriding damage factor in all treatments.

Despite satisfactory results from the above sequences, full-rate difenzoquat or L-flamprop-isopropyl applied at their optimum timings gave the best control of *A. fatua*, although only with the latter was this reflected in improved yield response and margin. The split treatment of difenzoquat did not improve yield response or *A. fatua* control compared with the full rate applied early.

The financial return from controlling *A. fatua* in spring barley with herbicides is, on the evidence presented here, disappointing. Increasing the price of barley to £90 per tonne reduces the number of negative margin treatments from twelve to nine, though it does improve the best return from £9 to £19 per ha. These poor returns suggest that spring barley, known to be a competitive crop, can tolerate considerable populations of *A. fatua*. However, if those populations are not controlled, they will become an increasingly damaging problem in other crops in the rotation, where their competitive effects may be more serious. Even in spring barley they will present harvesting and cleaning problems, the cost of which has not been considered in the interpretation of these results.

For this reason, the expense of a herbicide for *A. fatua* control in spring barley, except at very high populations, must be considered as an insurance against an unacceptable increase in *A. fatua* populations, in the rotation.

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THE IMPLICATIONS FOR WEED CONTROL IN DRY BULB ONIONS AND LEEKS WITH THE ADOPTION OF A NUMBER OF NEW CULTURAL PRACTICES

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Summary A number of new techniques, autumn sowing of bulb onions, fluid drilling, transplanting of plants in peat blocks, direct drilling and use of plastic mulches are described, and their advantages and disadvantages considered in relation to weed control in these crops. Emphasis is also placed on the importance of not only an improvement in the available herbicides but also in herbicide management.

Résumé Quelques techniques nouvelles, telles le semit des oignons en automne, le semis "fluid", la transplantation en blocs de tourbe, le semis direct, l'emploi de film plastique sont décrits. Les avantages et les inconvénients de ces techniques sont considérés par rapport au désherbage des cultures. On souligne aussi l'intérêt d'une amélioration non seulement des produits herbicides disponibles, mais aussi de l'emploi qu'on en fait.

INTRODUCTION

Effect of weed competition: Onions and to a lesser extent leeks, are slow to produce full ground cover and indeed in wide row crops never really do, and so are very prone to the effects of weed competition. A number of workers, including Bleasdale (1959), Whitwell (1969) and Hewson and Roberts (1971, 1973) have shown the effects on the marketable yield of spring sown onions, of weed competition during the first 6-8 weeks after 50% crop emergence; weeds that develop subsequently were shown not to affect yields.

These results clearly showed also, that if weeds germinating at or near the time of crop emergence remained until no more than 4-6 weeks after 50% crop emergence there was no reduction in yield. On plots not weeded until 7-8 weeks after 50% crop emergence, yield was reduced by 60% rising to 97% when the crop was left unweeded throughout its life.

The reduction in marketable yield was considered to be merely a reflection of the effect of the slow germination on the part of the onion crop, limiting the duration of vegetative growth, reducing the time available for full leaf cover to be achieved before bulbing commenced.

These results confirm the sensitivity of the onion crop to weed competition and it is likely that the drilled leek crop is affected in much the same way.

Spring drilled onions and leeks

On the silt soils in Lincolnshire, Whitwell (1969) after a series of experiments on the control of weeds in the drilled onion and leek crop considered that any chemical weed control programme should include a residual pre-emergence herbicide and the most consistent were propachlor and chloridazon plus chlorbufam. Results by Hewson and Roberts (1970) confirmed this but considered that on the mineral soil at the National Vegetable Research Station, Wellesbourne, propachlor was safer to use, chloridazon plus chlorbufam, even at lower than the recommended dose, causing unacceptable crop damage. They confirmed that best results were obtained by sowing, if possible into a stale seed bed and applying a tank mix of propachlor and paraquat shortly before the crop emerged. This ensures that all emerged seedling weeds are controlled.

At this time also it was considered that for spring drilled crops, inter-row cultivation in late May plus hand weeding in the row, followed by a further application of the residual herbicide was necessary. Chloridazon plus chlorbufam applied at the post-crook stage had been shown to be the most effective.

With the introduction of the contact herbicides, methazole, ioxynil, linuron and for the use on organic soils only, cyanazine, larger weeds can now be removed. Great care must be taken to ensure these chemicals are applied when the onion or leek plants have reached the required size and are seen to have a good covering of wax.

Recent trials with a combination of propachlor and chlorthal-dimethyl have produced promising results by extending the weed spectrum and reducing the problem of Polygonum spp. in particular.

Methabenzthiazuron has also shown up well in recent trials on the Ministry's Experimental Horticulture Stations being fairly safe to the crop when applied at the $2\frac{1}{2}$ leaf stage in October-November, depending on locality, and efficiently controlling grasses also Matricaria spp. and Tripleurospermum maritimum subsp. inodorum. However, by the $2\frac{1}{2}$ leaf stage, an early infestation of grass could be competing seriously with the crop and the chemical does not give a good control of emerged grasses. The chemical is not cleared under the Pesticides Safety Precautions Scheme on these crops at the present time.

New cultural practices discussed

Autumn sowing: Japanese and European varieties of onions, exhibiting greater winter hardiness and a shorter day length requirement for bulbing than traditional varieties, were introduced into the United Kingdom in 1970-71. By sowing the new varieties in the autumn, the crop could be harvested and marketed from early June, until the spring sown crop was harvested in the autumn. The autumn sown crop however brought with it new weed control problems.

Firstly, sowing date and emergence are critical. Sown too soon, the crop may bolt, sown too late, the plants may not be large enough to survive the winter. This could be aggravated by a check to growth from the pre-emergence herbicides used in the crop. Secondly, any damage caused by a contact herbicide in autumn could facilitate entry of Botrytis allii resulting in loss of plants during the winter.

There is also the behaviour of the herbicides themselves, particularly the persistance of the residual herbicides in this late summer-autumn period. Propachlor, which forms the basis of the pre-emergence weed control programme, is quoted as having an effective life of 6-9 weeks under spring and early summer conditions. However, in mid-August, when this crop is sometimes sown, the soil is warm, and, as irrigation is often applied to hasten germination, the herbicide may be quickly degraded resulting in a shorter effective life. Conversely, chlorpropham, which is rapidly lost by volatilisation when applied in the summer, can have a very long life if applied in the cooler weather of September, and the dose used for spring sown onions, could well not be safe on the late drilled autumn-sown crop.

The crop is often grown in a farm rotation following early harvested winter barley, early potatoes, peas and broad beans. This can mean a serious problem arising from volunteer plants from these crops, for which at present, there are no satisfactory herbicide to control them in the onion crop.

Finally, there is the weed spectrum likely to be encountered in the over-wintered crop. These are usually the same weeds that face the growers of winter oil seed rape. The big difference, is that the rape is much more competitive than onions.

Annual grasses are difficult to control post-emergence and methazole only takes out seedling grasses. Perennial grasses, eg Agropyron spp., are resistant to all onion and leek herbicides.

Composites, though well controlled by propachlor, are often a problem due to the limited life of the chemical.

Veronica spp. are controlled by the main residual herbicides, particularly, by chlorthal-dimethyl, but are not controlled by methazole.

Fumaria officinalis is resistant to most of the recognised onion and leek herbicides. See table 1.

Table 1

Susceptibility of some weeds to contact herbicides used on onions and leeks

	ioxynil	ioxynil + linuron	methazole	cyanazine
Poa annua	R	R	S	R
Fumaria officinalis	MS	S**	MR	MS
Lamium purpureum	MS	S	S*	S
Veronica hederifolia	MS	S	R	S
Matricaria spp.	S	S	MS	MS
Tripleurospermum spp.	S	S	MS	MS
Agropyron repens	R	R	R	R
Volunteer potatoes	R	R	R	R
Volunteer cereals	R	R	R	R

** by contact action only
 * at cotyledon stage only

S = susceptible   MS = moderately susceptible
R = resistant   MR = moderately resistant

Dry soil conditions can affect the performance of the residual herbicides and can also result in the seedling emergence of the crop being spread over a long period of time, making it difficult to time the application of contact herbicides. Also the autumn drilled crop is often more susceptible to damage from the application of contact herbicides, as the wax on the plants, which gives protection against the herbicides is less well formed in the generally cool moist conditions of autumn than in the hot dry summer period. Kirkwood (1972) reported that the superficial wax structure of some species are delicate and can be damaged by heavy rain, windblown soil, also the wind movement of any weeds in the crop, making the plants suceptible to damage from contact herbicides. One can observe this effect of weathering on the wax covering of the onion plant and, in particular, the autumn sown crop, growing at a time when extreme weather conditions are common.

Control of volunteer cereals in autumn sown onions

Roberts, Bond and Ricketts (1977) have shown that dalapon, applied at the dose of 1.7 kg ai/ha when the onions are at the 2 leaf stage, in combination with often routine application of methazole at 1.05 kg ai/ha, gives good control of cereals with the minimum of risk to the crop. On an organic fenland soil (UK, MAFF, 1977) damage to the autumn drilled onion crop, at much lower levels of dalapon were recorded.

Dalapon prevents the formation of wax on the new leaves formed after application putting the crop at risk from subsequent applications of contact herbicides, which may have to be applied later in the life of the crop. Even so, at present, dalapon is the only herbicide that can be recommended for the control of volunteer cereals in this crop.

Alloxydim sodium looks very promising in recent trials at Experimental Horticulture Stations and it is hoped that this herbicide will be developed to meet this need.

There is not the same weed problem in the spring sown crops, though early drilling, combined with low soil temperatures and poor seed bed conditions can result in the crop emerging over a long period, making the timing of the contact herbicide in relation to crop and weed growth difficult.

Two other new techniques that could help overcome this problem in the autumn as well as in the spring drilled crop are the introduction of fluid drilling with primed or perhaps already chitted seed. Also the development of the peat block plant raising system along with an automatic planting machine.

Fluid drilling

The technique developed at the National Vegetable Research Station (Salter,(1978) gets its name from the use of a viscose gel to support and protect the pre-germinated seed during the drilling operation. One of the main advantages so far obtained is the increased uniformity of emergence of some crops; results with the onion crop, however, have not been consistant.

If the technique is shown ultimately to be successful in its own right, it would simplify the timing of the application of post-emergence residual and contact herbicides and result in less risk of damage.

Peat block system

Recent experiments on the sowing of onion and leek seed into peat blocks, each block carrying 4-5 plants, and transplanting when the plants are anything from 6-7 weeks old has resulted, for certain sowings, in a marked increase in yield. The system is at present doubtful economically due to the cost of block making and of transplanting.

Collaboration between the National Institute of Agricultural Engineering, the National Vegetable Research Station and the Experimental Horticulture Stations is taking place to develop a system whereby the peat blocks are fed onto a transplanter mechanism for bandoliers, Boa (1972), to enable planting to be done automatically. This could result in a system requiring possibly only two operators which might well prove economic. With such a system the problem of getting plants all at a correct stage for applying contact herbicides, whilst the weeds are still very small, would be much easier.

The implication of transplanting is the greater depth protection which can be achieved, and the possibility of using a wider range of herbicides previously considered too damaging. However, in practice, with block raised plants, there is a tendency to shallow planting, thus, exposing the roots to damage from herbicides. This could be important with some currently used chemicals, which largely depend on depth protection for crop safety, eg methazole and chlorpropham.

Block plants are usually raised under protection and it is important that the seedlings are hardened off before planting, the hardening off process ensuring that the plants have adequate wax covering to protect them from post-planting herbicides. In order to preserve the wax covering present it is also necessary to handle the plant carefully all along the line, from the propagation area to the final position in the field.

Direct drilling

Elliott (1972). There is now a considerable hectarage of cereals and oil seed rape, roots and grass crops successfully produced on minimal cultivated land and the seed being drilled into the stubble of the previous crop. One advantage of direct drilling is the conservation of moisture in the top 2.5 cm of soil where the seed is deposited. This particularly, could provide an opportunity to exploit fluid drilling to greater advantage by placing the chitted seed into moist soil. In such a moist soil situation, a better performance of the residual herbicide is assured; this is most important as the system, besides requiring an absence of perennial weeds, relies heavily on the satisfactory control, of annual weeds.

Direct drilling of onions into a stubble is the subject of an investigation on the fen land soil of the Arthur Rickwood Experimental Husbandry Farm, MAFF (1977).

Use of plastic mulches

The temporary covering of drilled crops with transparent polythene film has been practised on the continent with some success Meijer (1978), and there is now experience of its use on a range of crops, including onions and leeks in the United Kingdom.

Although temperatures are not much higher under the mulch, approximately 2°C, one advantage is the retention of moisture which can improve the reliability of the residual herbicide, applied prior to covering.

The mulch can also result in germination taking place over a shorter period enabling the whole crop to reach the stage for the safe application of the contact herbicide sooner, before the weeds become too large to be killed or checked.

Further requirements for more reliable weed control in dry bulb onions and leeks

Application of existing herbicides. A better understanding of the conditions for not only more efficient weed control, but for reducing the risk of damage to the crop. Observations confirm that the present contact herbicides are often used when it is fairly obvious that the wax on the leaf has been damaged either by wind or rain. Spraying in the early morning or in the evening when there is less air movement, is often practiced to reduce the risk of drift damage to adjacent crops. Under these conditions the herbicide droplets tend to remain longer on the leaves allowing the chemical to become absorbed by the plant. This is also more likely to happen when the humidity is high.

Possibly the safest time to use these contact herbicides is during the day in good evaporative conditions, provided the crop is not under too much stress.

A closer look at an integrated system of weed control where good cultural management is linked with efficient herbicides, eg more use of the stale seed bed, or a period of fallow prior to the crop being drilled.

The exploitation of a suitable crop rotation enabling problem weeds to be controlled in the previous crop.

New herbicides There is a need for more persistent residual herbicides. This would reduce the need for the post-emergent contact herbicides which damage the onion foliage. This is particularly relevant to the autumn sown onion crop. It would probably be an advantage if such herbicides could be incorporated to improve their reliability.

Also required are chemicals to control the volunteer crops of cereals and potatoes in the leek and onion crop.

New herbicides tend to be more and more specific, controlling a narrower spectrum of weeds, so that more consideration should be given to either herbicide mixtures or to successive applications of complementary herbicides in a programme.

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WEED CONTROL PROGRAMME FOR RED BEET

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Summary The most prevalent weeds were *Urtica urens*, *Poa annua*, *Matricaria* spp. and *Stellaria media*. None of the treatments significantly effected plant stand. All the pre-emergence herbicide treatments except lenacil plus ethofumesate significantly controlled weeds and all 3 post-emergence treatments gave excellent weed control. None of the pre-emergence treatments significantly affected yield. Of the post-emergence treatments, yields were significantly higher with metamitron. The best overall treatment was pre-emergence propham + fenuron + chlorpropham + pyrazon mixture followed by metamitron post-emergence.

Résumé Les adventices les plus importants étaient *Urtica urens*, *Poa annua*, *Matricaria* spp. et *Stellaria media*. Aucun des traitements n'a eu d'influence significatif sur la densité depeuplement. Tous les traitements de pré-levée, sauf le lenacil plus l'ethofumesate ont assuré une bonne destruction des adventices et les 3 traitements de post-levée ont assuré un desherbage excellent. Les traitements de pre-levée n'ont guère en d'influence sur les rendements tandis qu'en post-levée le metamitron a augmenté les rendements de façon significative. En général le meilleur traitement consistait en un mélange de propham + fenuron + chlorpropham + pyrazon en pre-levée suivi de métamitron en post-levée.

INTRODUCTION

The trial included metamitron which has the Approval of the Agricultural Chemicals Approval Scheme for use on sugar beet with interest by the manufacturers for Approval on red beet. This chemical controlled a fairly wide range of weeds.

Work at the National Vegetable Research Station (NVRS) (1974, 1975 and 1976) showed red beet to be relatively tolerant to metamitron applied both pre- and post-emergence. Another herbicide used for weed control in sugar beet, ethofumesate, when applied pre-emergence caused no crop injury but gave inadequate weed control at NVRS (Roberts and Bond, 1973), whereas results there were excellent when it was combined with lenacil or pyrazon. Ethofumesate plus lenacil was Approved for use on fodder beet, sugar beet and mangolds, and it was decided to examine this herbicide mixture on red beet. Pyrazon combined with half dose propham + chlorpropham + fenuron is not recommended by the two manufacturers for red beet but is used by fodder-sugar beet growers and this mixture was included in the treatments studied. Lenacil plus phenmedipham mixture post-emergence is an Approved treatment and was included to compare with phenmedipham alone. Lenacil, pyrazon and phenmedipham were compared in a trial at Stockbridge House Experimental Horticulture Station in 1968.

METHODS AND MATERIALS

Soil type: the soil type was a fine sandy loam of the Skipworth series overlying lacustrine clay. It caps in heavy rain and is liable to blow when dry.

Experimental layout: pre-emergence treatments; 4 replicates of 8 treatments (5 chemicals plus 3 controls) in randomised blocks. Post-emergence: no replication, one of four post-emergence treatments to each of the four replicates of the pre-emergence treatments.

Methods and timing of application: variety Dwergina sown on 22 June 1977. The herbicides were applied by a Knapsack sprayer in 784 litre/ha.

Treatments applied:
pre-emergence;
propham 1.05 + fenuron 0.18 + chlorpropham 0.26 kg ai/ha
lenacil 0.88 kg ai/ha
lenacil 0.88 kg ai/ha plus ethofumesate 1.0 kg ai/ha
metamitron 3.5 kg ai/ha
propham 0.53 + fenuron 0.09 + chlorpropham 0.13 + pyrazon 1.28 kg ai/ha
control no herbicide (3 plots)

post-emergence;
phenmedipham 0.8 kg ai/ha
metamitron 3.5 kg ai/ha
lenacil 0.88 + phenmedipham 0.8 kg ai/ha
control no herbicide

The pre-emergence treatments were all applied 3 days after drilling. The post-emergence treatments were all applied at the 2 true leaf stage.

Method of recording: plant stand counts from 6 x 1.5 metre row were taken prior to application of the post-emergence treatments, and repeated 3-4 weeks later. Weed counts from 10 x $30cm^2$ quadrats were taken prior to application of the post-emergence treatments, recording the weeds by species. An estimate of percentage weed cover was also taken. Nineteen days later a further assessment was made taking the percentage total weed cover and the proportion of this cover attributable to each species. Time taken to hand weed the plots was then taken. Hand weeding consisted of hand pulling the biggest weeds in a manner similar to that undertaken commercially.

RESULTS

Plant stands on 15 July, 18 days after the pre-emergence sprays were applied, showed no significant effect on plant stand by any treatment as shown in table 1.

Table 1

Mean plant stand/m of row on 15 July before post-emergence treatments

propham fenuron chlorpropham	lenacil	lenacil + etho-fumesate	metamitron	propham fenuron chlorpropham + pyrazon	control	control	control
23.66	26.86	22.84	22.43	23.90	24.64	26.34	24.70
			S.E. ± 1.518				

Stand counts repeated on 2 August 2 weeks after the post-emergence sprays (table 2) shows no significant differences and very low losses overall.

Table 2

Plant stand/m of row on 2.8.77, 2 weeks after application of post-emergence treatments

(mean of 4 post-emergence treatments)

propham fenuron chlorpropham	lenacil	lenacil + etho-fumesate	metamitron	propham fenuron chlorpropham + pyrazon	control	control	control
24.67	26.04	24.01	22.95	24.18	25.79	26.58	25.03

S.E. ± 1.857

Weed assessments were made on 19 July prior to the application of the post-emergence treatments. The weeds were counted by species from 10 x 30 cm^2 quadrats per plots, (table 3) and an estimate made of the % ground cover of the weeds (table 4). U. urens was the most prevalent weed, but even this was present in a very irregular number, and is reflected in the high standard error. Even so there was a clear indication from the estimated % weed cover that all the pre-emergence treatments except lenacil + ethofumesate gave a significant level of weed control. The lack of effect of this treatment is accounted for by unusually high numbers of U. urens seedlings on one of the plots. The metamitron treatment would also have performed better but for a similar occurrence in one of the plots. Propham + fenuron + chlorpropham + pyrazon gave the best weed control both in terms of reduction in numbers of weeds, and in % of weed cover, in particular giving complete control of Poa annua. By the same standard metamitron was the second most successful treatment. However, of the five treatments, these two gave the least control of P. aviculare. X This again illustrates the irregular nature of the weed scatter as propham + fenuron + chlorpropham, without the addition of pyrazon gave complete control of this weed. It is known from their use in sugar beet, that of these herbicides only metamitron is inherently weak against polygonums.

Table 3

Weed assessment 19.7.77 before application of post-emergence treatments
No. of weeds by species as % of mean numbers on 3 control plots

Pre-emergence treatments	Urtica urens	Stellaria media	Matricaria spp.	Poa annua	Polygonum aviculare	Others
propham + fenuron + chlorpropham	36.62	70.83	59.41	44.64	37.50	61.36
lenacil	42.25	41.67	8.91	39.29	0.00	40.91
lenacil + ethofumesate	132.39	8.33	2.97	7.14	0.00	27.27
metamitron	87.32	54.17	5.94	1.79	75.00	20.45
propham + fenuron + chlorpropham + pyrazon	33.80	41.67	2.97	0.00	36.50	75.00
control 1	98.59	95.83	80.20	128.57	150.00	102.27
control 2	146.48	133.33	157.43	146.43	150.00	95.45
control 3	54.93	70.83	62.38	25.00	0.00	102.27
mean	79.95	64.58	47.52	49.11	56.25	65.62

Table 4

Weed assessment 19.7.77 before application of post-emergence treatments

Estimated % weed cover

Pre-emergence treatments	% weed cover
propham + fenuron + chlorpropham	8.75
lenacil	10.00
lenacil + ethofumesate	18.50
metamitron	8.25
propham + fenuron + chlorpropham + pyrazon	5.00
control 1	38.00
control 2	33.75
control 3	14.25
mean	17.06
S.E. ± 5.94	

A further weed assessment 2 weeks after application of the post-emergence treatments showed significant weed control by all 3 post-emergence chemicals (table 5) but no significant differences between them (averaged over 8 pre-emergence treatments).

Table 5

Weed assessment 2 weeks after post-emergence application. % of total weed cover by species plus overall % weed cover

	Urtica urens	Stellaria media	Matricaria spp.	Poa annua	Polygonum aviculare	Others	% weed cover
phenmedipham	17.88	0.0	16.88	9.25	30.63	0.38	1.50
metamitron	2.50	0.0	15.63	35.63	4.88	28.88	1.13
lenacil + phenmedipham	58.25	0.0	4.38	4.13	3.38	4.88	5.75
control	76.13	0.63	7.38	4.00	3.50	8.38	36.50
mean	38.69	0.16	11.06	13.25	1.25	6.75	13.00
							S.E. ± 4.55

N.B. percentage weed species do not always total 100% because several plots were completely weed-free, but included in the mean figure.

Metamitron marginally gave the best overall weed control but P. annua and Chenopodium album survived this treatment. U. urens was by far the most prevalent species at this stage as judged by the untreated control and metamitron was particularly effective against this weed. Matricaria spp. were second most prevalent and all 3 post-emergence herbicides gave a similar reduction of this weed (75%).

All plots were then hand weeded on 8 August and timed (table 6). All post-emergence sprays significantly reduced weeding times but there was no significant differences between the 3 materials averaged over all 8 pre-emergence treatments.

Harvesting occured on 20 October. Roots were counted and weighed in 2 size grades viz up to 2.5 cm and over 2.5 cm. Yields of roots over 2.5 cm diameter from the 8 pre-emergence treatments, meaned over the 4 post-emergence treatments showed no significant differences (table 7).

Table 6

Time to handweed plots (mins) 8 August 3 weeks after post-emergence sprays applied (plot size 18 m^2)

pre-emergence treatments	phenmedipham	metamitron	lenacil + phenmedipham	control	Mean
	post-emergence treatments				
propham + fenuron + chlorpropham	0.75	0.98	0.50	3.75	1.50
lenacil	0.76	1.25	2.25	3.00	1.82
lenacil + ethofumesate	0.66	1.25	2.83	6.91	2.94
metamitron	0.50	1.58	0.50	7.83	2.60
propham + fenuron + chlorpropham + pyrazon	0.75	0.71	1.75	0.83	1.01
control	2.75	2.83	5.20	8.15	4.52
control	0.91	3.28	5.00	10.50	5.00
control	3.00	2.75	0.62	8.83	3.81
mean	1.26	1.73	2.34	6.49	2.96
S.E. ± 0.614					S.E. ± 0.868

Table 7

Yield (tonnes/ha) of roots over 2.5 cm diameter

pre-emergence treatments

propham + fenuron + chlorpropham	lenacil	lenacil + ethofumesate	metamitron	propham + fenuron + chlorpropham + pyrazon	control	control	control
55.95	54.47	54.12	52.15	51.82	51.22	50.35	54.97

S.E. ± 2.741

The post-emergence treatments, meaned over the 8 pre-emergence treatments, showed a small significant advantage from metamitron (table 8) compared to the control or other post-emergence treatments.

Table 8

Yield (tonnes/ha) of roots over 2.5 cm diameter

post-emergence treatments

phenmedipham	metamitron	lenacil + phenmedipham	control
48.96	60.54	51.85	51.19

S.E. ± 1.938

This increase in marketable yield was partly due to higher plant numbers on the metamitron plots exceeding 2.5 cm diameter compared to the control (table 9), but also in part to slightly heavier mean root weight, since the numbers were not significantly higher than the other post-emergence treatments or the control. This supports the crop safety aspect reported by Roberts (1973, 1975 and 1976).

Table 9

Number of roots per sq metre over 2.5 cm diameter

post-emergence treatments			
phenmedipham	metamitron	lenacil + phenmedipham	control
59.1	58.9	52.4	49.1
S.E. $\pm$ 2.907			

Root numbers over 2.5 cm diameter on all 8 pre-emergence plots averaged over the 4 post-emergence treatments showed no significant differences between any treatments (table 10). If growing for a specific size outlet all the treatments are equally satisfactory.

Table 10

Mean number of roots per m^2 over 2.5 cm diameter

pre-emergence treatments							
propham + fenuron + chlorpropham	lenacil	lenacil + ethofumesate	metamitron	propham + fenuron + chlorpropham + pyrazon	control	control	control
58.0	58.1	54.9	51.4	49.8	55.7	57.1	54.2
S.E. $\pm$ 4.109							

DISCUSSION

As none of the pre-emergence treatments affected plant stand or yield it seems advisable to choose the one most suited to known weed species present and relatively cheap. The cheapest is propham + fenuron + chlorpropham. The weed spectrum for this herbicide is generally good but weak on U. urens, P. annua and Matricaria spp. Adding pyrazon to the mixture gave complete control of P. annua and substantially improved control of U. urens and Matricaria spp. The best control of P. aviculare, S. media and Matricaria spp. was lenacil + ethofumesate. Of the post-emergence materials metamitron was the most expensive but seems justified by increasing yields. If C. album or P. annua are problem weeds phenmedipham would be preferable. If Polygonum spp. are prevalent lenacil added to the phenmedipham should control them.

This work tends to confirm the crop safety of ethofumesate used pre-emergence on red beet on a fine sandy loam when mixed with lenacil, and shows its effect on enhancing control of P. annua, S. media and Matricaria spp. but its effect on U. urens was reduced.

Since this paper was prepared it is evident from the 1978 trials that ethofumesate can cause crop check and is not so safe on red beet as the 1977 results indicated.

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