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COST-EFFECTIVE WEED CONTROL IN SPRING BARLEY IN THE NORTH OF SCOTLAND

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Summary The relationship between weed numbers and the yield of spring barley has been determined for different weed species and is used to discuss the cost-effectiveness of control measures. It is concluded that for certain annual dicotyledon weeds the cost of control is so low in relation to the potential benefit that it is unnecessary to attempt to define the break-even point. For *Avena fatua* it is more important to relate treatment costs to the density of infestation but there are many fields where a generous yield response will be obtained. The cost of *Agropyron repens* control is high and the size of the yield response is lower than with other weeds; however the benefit of control will continue over several years and this may justify treatment.

INTRODUCTION

The main objective of controlling weeds in cereals is to prevent them causing loss in crop yield. Other forms of loss due to the presence of weeds, such as interference with harvesting and contamination of crop produce, are also important but are difficult to quantify. In general it is desirable that removal of weeds should lead to an increase in crop yield sufficient to pay for the cost of herbicides plus their application.

The cost of controlling weeds in spring barley varies widely according to the species present. Often two or even three different treatments are needed for complete weed control, e.g. control of *Agropyron repens* by pre-sowing glyphosate application followed by post emergence *Avena fatua* and annual dicotyledon weed control. The costs of such a programme are additive, although some saving in the cost of application can be made by tank mixing compatible herbicides. In Table 1 a simplified calculation is made of the percentage increase in crop yield which must follow removal of weed competition if their control is to be justified by yield response alone. Obviously in lower yielding crops a greater percentage yield response is needed to cover the cost of control.

For MCPA sensitive species the cost of treatment is low and in practice few farmers are likely to hesitate before treating even light infestations. On the other hand the costs of *Avena fatua* and *Agropyron repens* control are relatively high and substantial yield responses are needed to repay the cost of treatment. Previously it has been difficult to give advice on which a rational decision could be based, as there is relatively little scientific information available on the effects of different weed species and densities on crop yield under varying environmental and husbandry conditions.

Work has been carried out at the North of Scotland College of Agriculture to determine which weed species are common in spring barley, to measure their density and to relate weed numbers to loss in crop yield. *Avena fatua* has been given most attention but *Agropyron repens*, *Galeopsis* spp. and *Sinapis arvensis* have also been

Table 1

Increase in yield required to cover cost of control of weeds in spring barley

Weed problem	Cost of control £/ha	Equivalent weight of grain kg/ha	Equivalent % yield response
MCPA sensitive species	7.50	80	1.8
Stellaria media and *Polygonum spp.*	13	138	3
Avena fatua	34	362	8
Agropyron repens	45	480	10

Assumed price of barley £94/tonne, cost of spraying £4.50/ha, average yield of spring barley 4.5 tonnes/ha.

studied. Linear regression has been used to correlate actual crop yield with weed numbers, comparisons between sites and species being made on a percentage yield basis.

RESULTS

a. Annual dicotyledon weeds

A survey by Carnegie (1974) showed that *Stellaria media*, *Galeopsis spp.*, *Spergula arvensis*, *Polygonum aviculare* and *Polygonum persicaria* are the most important annual dicotyledon weeds in the north of Scotland. The herbicides used by farmers for their control are shown in Table 2. MCPA is still the most widely used material.

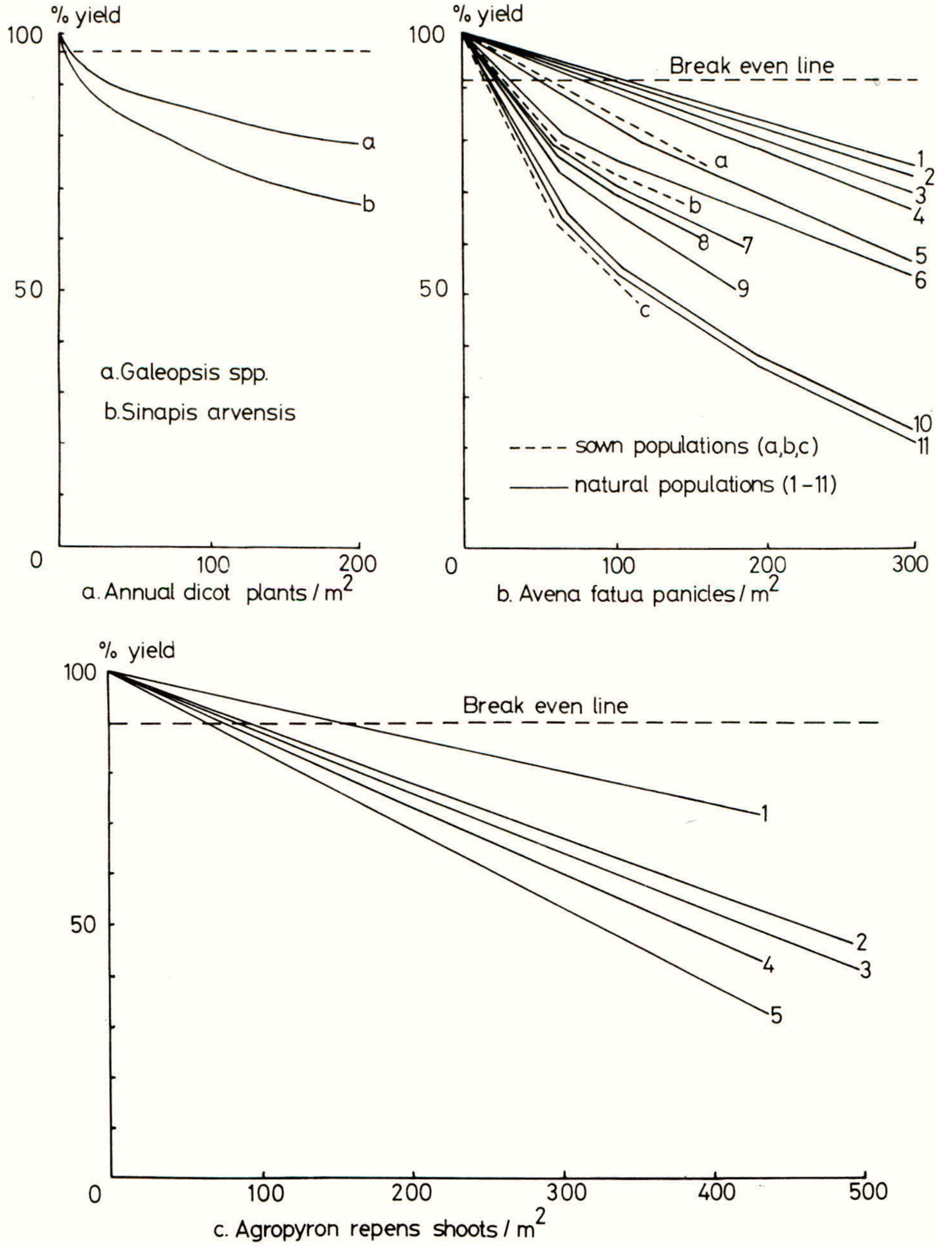
Table 2

Herbicide usage on spring barley in north east Scotland 1977

	% of fields
None applied	19
MCPA	42
MCPB or 2, 4-DB or benazolin mixtures	13
Dicamba or dichlorprop/MCPA mixtures	13
Others	13
Avena fatua herbicides	4
Agropyron repens herbicides	2

Based on information collected during the 1977 National Wild Oat Survey

FIG.1 EFFECT OF WEEDS ON YIELD OF SPRING BARLEY
[See Appendix 1 for Regression Equations]



In 1967 a yield comparison was made between treated and untreated strips in sprayed crops (Scragg 1970). A small overall mean yield increase on the treated strips was recorded. Large increases were found in potentially low yielding crops with high densities of weed infestation. Where Sinapis arvensis, Raphanus raphanistrum, Chrysanthemum segetum and Lycopsis arvensis were present substantial yield increases occurred even in good competitive crops. Many good crops showed little response to annual dicotyledon weed control. On the other hand there was no evidence for widespread yield reductions as reported by Evans (1968) in England.

Recent work has attempted to correlate the density of Sinapis arvensis and Galeopsis spp. with yield loss in spring barley. Figure 1a shows the relationships obtained from two small-plot field experiments exploiting natural variations in weed density. Substantial yield losses were detected comparable to those reported by Wells (1979) for annual dicotyledons in wheat in Australia. Our results and those of earlier pot experiments (Scragg & McKelvie (1976)), show a curvilinear relationship with marked initial depression of yield at quite low densities followed by a diminishing rate of change at high weed numbers. We have not found the linear response described by Wells for four out of five of the weeds he examined. Our results are similar to the response he describes for Lamium amplexicaule except that our weed densities are much lower.

b. Avena fatua

The results of the national survey of grass weeds (Elliott et al (1979)) and our own survey (Scragg, Kilgour & Carnegie (1976)) show that Avena fatua is a major weed in the area, in spite of which only 4% of fields were sprayed with appropriate herbicides in 1977.

Some information is available on the cost effectiveness of Avena fatua control including the work of Smith & Finch (1978) which showed that often in the east of England yield response was insufficient to pay for the cost of treatment except at very high weed densities.

We have been unable to carry out trials similar to those of Smith & Finch mainly because of the unacceptability of unsprayed plots in densely infested fields. It has been possible to exploit missed strips in commercially treated crops and the results of four determinations are shown in Table 3. All sites were sprayed with difenzoquat at the full recommended rate and excellent control of Avena fatua was achieved. Large increases in yield, amply sufficient to pay for the cost of treatment, were recorded except at site A where spraying was delayed until the flag leaf stage of the crop.

Table 3

Results of Avena fatua control with difenzoquat

Site	Mean panicles /m^2	Mean yield unsprayed g/m^2	% increase in yield
+A 1977	172	530	8.8 n.s.
B "	291	401	47.9 ***
C 1978	138	326	27.6 **
D "	348	233	68.1 ***

+ sprayed at flag leaf stage

Attempts have also been made to measure the effect of different numbers of Avena fatua on yield of spring barley without the use of herbicides. At eleven sites during 1975-78 natural variation in density within infested fields was exploited. In each field 20-30 samples each 1 m^2 were collected and crop yield correlated with the number of Avena fatua panicles present. This method suffers from the basic defect that high Avena fatua numbers may be a consequence of a poor crop not its cause.

More recently Avena fatua seeds have been sown at varying densities in previously clean ground as was done by Dew (1972) in Canada. It has proved difficult to achieve the high densities of wild oats (often 3-400 panicles/m^2) found in natural infestations. This technique allows the effect of factors such as date of sowing, seed rate and levels of fertility to be investigated. The results of deliberate sowing of Avena fatua have been very similar to those obtained from sampling natural infestations (Figure 1b).

There is large site to site variation in the effect of Avena fatua on the yield of spring barley. We have not found the square root relationship given by Dew and confirmed by Hamman (1979) for Canada to hold good for all situations. In fields where Avena fatua has little effect a straight line gives the best correlation, with a gradual change to a strongly curvilinear relationship on sites where competition is severe. Insufficient work has been done to evaluate the factors influencing the severity of competition but it is clear that relative time of emergence of crop and weeds and seed rate are important.

c. Agropyron repens

This weed is widespread in the north of Scotland (Elliott et al (1979)). It is regarded by farmers as a serious problem and in the past has received more attention than Avena fatua.

Limited work exploiting differences in Agropyron repens shoot density resulting from post-harvest glyphosate treatment (3 sites) and from natural variation (2 sites) has given the relationships shown in Figure 1c. Very high densities of Agropyron repens shoots were encountered and these caused serious loss in yield. At densities of up to 100 shoots/m^2 only small yield losses were recorded. In every case a straight line gave the best correlation between shoot numbers and crop yield.

DISCUSSION

The results of our work show that in the north of Scotland weeds can cause large losses in crop yield and that their control by selective herbicides is likely to be highly cost effective on most occasions. Certain of the annual dicotyledon weeds prevalent in the area are very competitive and as the cost of their control is low it is wise to eliminate them even at low densities of infestation. Work is needed on species such as Stellaria media and the Polygonum spp. which may be less competitive than the common MCPA sensitive weeds. Although the cost of their control is appreciably higher it still requires a very small increase in yield to pay for the cost of treatment. When the additional benefit of easier harvesting is taken into account it seems likely that annual dicotyledon weed control in cereals with selective herbicides will continue to be a normal part of cereal husbandry in most fields.

The case for Avena fatua control also seems to be justified on yield response grounds in many infested fields. The variation from site to site is so great that it is not possible to precisely define the weed density at which a yield increase large enough to cover the cost of treatment will be obtained. Also to be taken into account is the damaging effect of some *Avena fatua* herbicides on cereal crops. Smith & Finch attach considerable importance to this factor in their assessment. Because of this risk spraying of lightly infested fields should only be carried out where *Avena fatua* eradication is the ultimate objective. In practice many fields in the north of Scotland are so heavily infested that eradication is impossible, containment and maximum economic benefit are more realistic objectives. Under these conditions it is essential to relate treatment costs to probable loss in yield.

In general yield loss due to *Avena fatua* in the north of Scotland is more in line with that reported by Rola & Rola (1976) for Poland than by Smith & Finch or Chancellor & Peters (1974) for England. It is likely that the cool damp climate and moist soils so favourable to cultivated oats production also result in vigorous *Avena fatua* growth. The results of our local annual survey indicate that at least double the 4% of area currently sprayed for *Avena fatua* could with profit be treated as we have consistently recorded 3-4% of heavily infested fields and an additional 10-12% of medium infested fields in our pre-harvest inspection.

The case for *Agropyron repens* control is less certain as not only is the cost of control high but the likelihood of a substantial increase in crop yield is lower. In trials with glyphosate Hodkinson (1974) reported no significant increase in yield at 13 sites in spite of excellent weed control. Cussans (1970) showed that of the crops tested spring barley was the most competitive with *Agropyron repens*. Our work indicates that with massive infestations, which are quite common, a good yield response is likely and the cost of treatment can be recovered in one season. In lighter infestations the benefit of control spread over several seasons may still justify treatment.

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Appendix 1

Regression equations for Figure 1 from which percentage yields calculated for comparison purposes.

$y = a - bx$; y = predicted barley yield, a = y intercept, b = slope, x = no. of weeds

a. Annual dicotyledons

a. **Galeopsis tetrahit**	$y = 668.9 - 10.89\sqrt{x}$		$r = -0.7981$
b. **Sinapis arvensis**	$y = 496.1 - 14.34(\sqrt{x} - \frac{x}{80})$		$r = -0.7709$

b. **Avena fatua**

Field sites

1	Newseat	$y = 329.8 - 0.2510x$	$r = -0.7423$
2	Townhead	$y = 375.2 - 0.3716x$	$r = -0.8660$
3	Enzie	$y = 629.1 - 0.6462x$	$r = -0.9334$
4	New Craig	$y = 662.7 - 0.8889(x - \frac{x^2}{2000})$	$r = -0.8774$
5	Esslemont	$y = 538.7 - 1.2788(x - \frac{x^2}{1000})$	$r = -0.8706$
6	Dykehead	$y = 628.3 - 17.25\sqrt{x}$	$r = -0.8822$
7	Gownor	$y = 560.8 - 16.09\sqrt{x}$	$r = -0.8410$
8	Woodend	$y = 619.3 - 19.38\sqrt{x}$	$r = -0.6745$
9	Backpark	$y = 643.1 - 21.11\sqrt{x}$	$r = -0.9131$
10	Kinkell 1974	$y = 668.1 - 30.08\sqrt{x}$	$r = -0.9282$
11	" 1975	$y = 525.3 - 24.28\sqrt{x}$	$r = -0.9205$

Craibstone plots

a	late sown 1979	$y = 360.2 - 0.5988x$	$r = -0.6899$
b	late sown 1978	$y = 440.8 - 12.60\sqrt{x}$	$r = -0.7795$
c	early sown 1978	$y = 471.0 - 22.67\sqrt{x}$	$r = -0.8320$

c. **Agropyron repens**

Field sites

1	Townhead	$y = 446.2 - 0.3120x$	$r = -0.8220$
2	Esslemont	$y = 551.8 - 0.5801x$	$r = -0.5801$
3	Kaim	$y = 643.1 - 0.7590x$	$r = -0.9201$
4	Balnastraid 1976	$y = 460.9 - 0.6040x$	$r = -0.8596$
5	Balnastraid 1975	$y = 418.3 - 0.6412x$	$r = -0.9382$

THE INFLUENCE OF APPLICATION TIMING ON CEREAL YIELD OF PRODUCTS BASED ON SUBSTITUTED PHENOXY ALKANOIC HERBICIDES

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Summary Frequently post-emergence herbicides cannot be applied at the optimum time and farmers may well decide to spray outside recommended crop growth stages.

To assess the effects of this practice on yield, 23 years' data from a large number of replicated trials have been collated, and results comparing applications over a range of crop stages, both in the presence and absence of broad-leaf weed, covering a range of 17 products based on substituted phenoxy alkanoic acids are presented.

In the absence of weed, yields were not depressed following application of products at their recommended rates before the first node stage. Following application at this stage or later, the incidence of yield reduction at product recommended rates was slight but at higher rates was more frequent. With moderate weed populations, no yield reductions occurred either at recommended or higher rates of use but with high weed populations yields were generally increased, irrespective of growth stage.

Résumé Il n'est souvent pas possible d'appliquer des herbicides de post-levée à l'époque convenable. L'agriculteur peut alors decider de les utiliser en dehors des stades phenologiques recommandés.

Pour évaluer l'incidence de cette pratique sur les rendements, on a compilé les résultats de 23 années d'essais. Puis on a comparé ces résultats d'application realisés à travers un large éventail de stades phenologiques soit en présence soit en absence d'adventices dicotyledones. 17 produits a basé d'acides phenoxy-alcanoiques sont ainsi présentés.

En l'absence d'adventices les rendements ne sont pas diminués consécutivement à l'application des produits utilisés à la bonne dose et avant le stade du premier noeud. Les applications faites à la dose recommandée et à ce stade ou ultérieurement induisent une légère diminution de rendement tandis que les doses fortes provoquent des dépressions plus frequentes. En présence de populations moyennes d'adventices, aucune diminution de rendement ne se produit soit à dose normale soit à dose forte. Par contre des rendements sont augmentés en présence de fortes populations d'adventices quelque soit le stade d'application du produit.

INTRODUCTION

The advantages of timely application of post-emergence cereal herbicides for safe and effective broad-leaf weed control have been emphasised in recent years by Evans (1974) and Tottman and Duval (1978) and are widely recognised and accepted. In practice, however, what risks, if any, does the farmer take when not uncommonly he is forced to spray outside optimum crop growth stages? To provide some answers to this question, results from yield trials covering 23 years and conducted in weedy and weed free fields, have been collated. These trials were originally designed to evaluate new products. In the early years, those tested were based solely on the substituted phenoxy alkanoic acids, MCPA, 2,4-D, mecoprop and dichlorprop. In later years, mixed products based on these materials, MCPB or 2,4-DB and including one or more of the following, benazolin, dicamba or 3,6-dichloropicolinic acid, were also included. Relevant yield data from these trials covering 17 products applied over a range of crop growth stages are considered in the paper.

METHOD AND MATERIALS

For yield determination, weed free sites were generally selected in order to assess the direct effect of herbicide treatment on the crop. However, a substantial number of sites with moderate to high weed populations susceptible to the products applied were also selected and taken to yield. At the majority of sites, treatments were applied at two or more crop growth stages thus enabling relevant comparisons to be made between weedy and clean sites. Site, method and materials data for the 78 trials conducted between 1957 to 1979 inclusive are summarised below:-

Type of site: Number with no or negligible weed - 59

Number with moderate to heavy weed - 19

Crops: Autumn and spring sown crops of wheat, barley, oats and rye

Plot size and replication: 40 m x 2.7 m x 6

Application: by Lenton Small Plot Sprayer (Lush and Mayes 1972)

Water Volume: 200 l/ha pressure 2.1 bar

Timing of application: Crop stages from ZCK 11 to ZCK 43

Growth stages recorded in accordance with Zadoks' scale (Zadoks et al 1974)

Most advanced stage recommended for products evaluated = ZCK 30

Harvest equipment: Combine harvesters specifically adapted for small plot work

Treatments: 17 products applied at recommended (r) rate, r x $1\frac{1}{2}$ and r x 2, in comparison with unsprayed control. At one location a handweeded control was also included.

Products formulated as amine or alkali metal salts, based on the substituted phenoxyalkanoic acids, 2,4-D, MCPA, mecoprop, dichlorprop, MCPB, 2,4-DB with or without the addition of one or more of the following, benazolin, dicamba or 3,6-dichloropicolinic acid.

Assessment: Grain weight adjusted to a common moisture content each season.

Weed on a 0-10 scale. 0 = no effect
7 = acceptable
10 = complete kill

Assessment of weed population and weed control was necessarily restricted to avoid mechanical damage to the crop.

RESULTS

No or negligible broad-leaf weed present

At recommended rates in the absence of weed, yield was unaffected by application before the first node stage (ZCK 31) whilst at this or later stages, yield decreases were recorded only twice. They were more frequent at increased doses (Table 1 and Figure 1). Yield reductions of 6-13% were recorded but variation within this range could not be ascribed to specific treatment (Table 1). Nor could the incidence of yield reduction be correlated with the product or the year of application.

Table 1

Effect of treatment timing and rate on yield

No or negligible weed present

Crop stage at application and rate of use (r = recommended rate)		Yield < untreated p = 5%	Yield < untreated p = 1%	Yield = untreated
		Number of comparisons ( ) = range of yield reduction		
before ZCK 30 (winter) or ZCK 15 (spring cereal)				
	r	0 (9%)	0	37
	rx1½	2 (8-9%)	0	25
	rx2	0	0	13
at ZCK 30 (winter) or ZCK 15-30 (spring cereal)				
	r	0	0	67
	rx1½	0	0	59
	rx2	5 (6-13%)	4 (6-11%)	44
at ZCK 31 or later				
	r	1 (14%)	+1 (19%)	61
	rx1½	5 (5-10%)	5 (8-10%)	50
	rx2	6 (5-13%)	3 (5-13%)	39

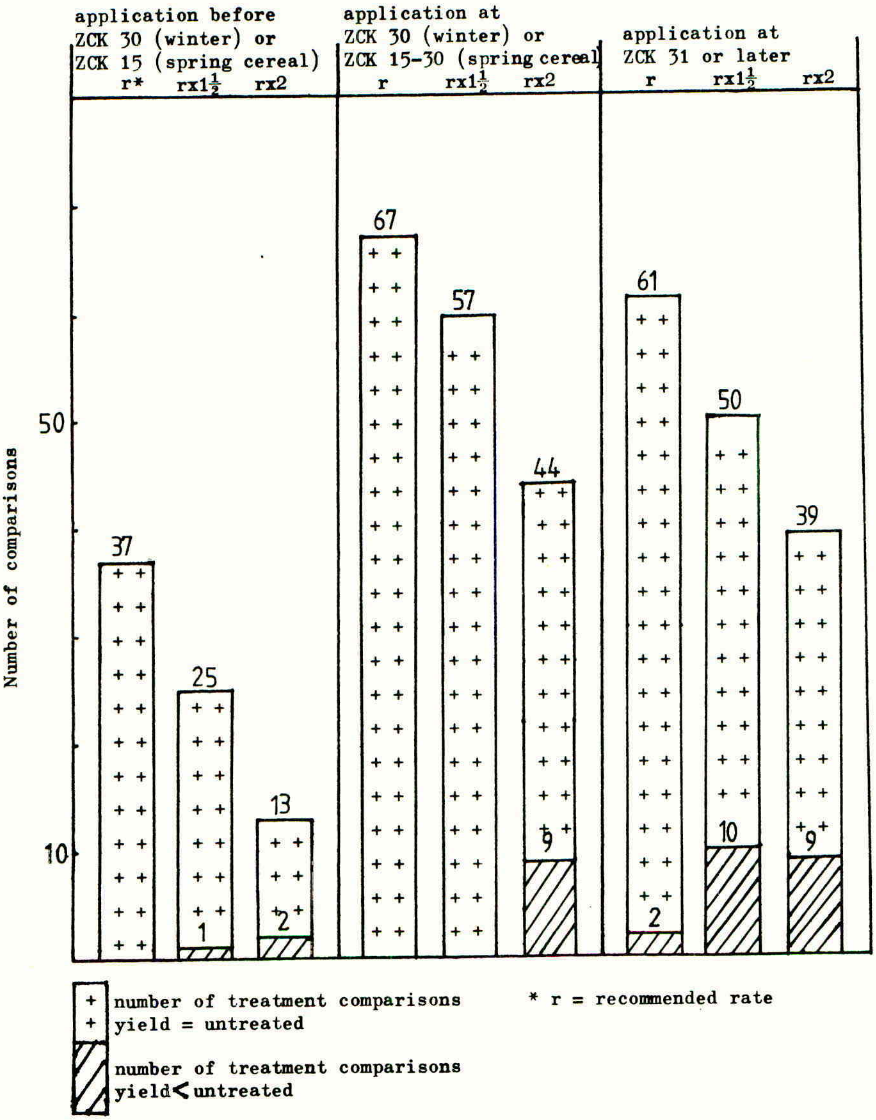
+ = application at ZCK 43 (boot stage) range of experimental standard error = 1.5-5.1%

Figure 1

Effect of treatment on yield

No or negligible weed present

Number of comparisons yield reduced v number yield equal to untreated



Moderate to high weed populations of broad-leaf weed present

In the presence of weed, no yield losses occurred irrespective of rate, (Tables 2-4). With increasing weed population yield increases were more frequent, (Tables 2 and 3).

The incidence of yield increase was very similar for recommended, x1½ and x2 rates of product use, the potential for further yield improvement being largely precluded by the very high weed control standard achieved, (Table 4). That in fact the frequency of yield increases was not diminished at the x1½ and x2 rates is an indication of the crop selectivity of the products used.

Significant yield increases of 5-34% were recorded but within this range, variation cannot be ascribed to specific treatment.

Table 2

Effect of treatment timing on yield at product recommended rates

Moderate to high populations of broad-leaf weed present

Crop stage at application and weed population	Yield < untreated	Yield = untreated	Yield > untreated at p = 5%	p = 1%
		number of comparisons ( ) = range of yield increase		
before ZCK 30 (winter) or ZCK 15 (spring cereal)				
moderate	0	9	1 (12%)	3 (10-16%)
high	0	0	0	3 (26-32%)
at ZCK 30 (winter) or ZCK 15-30 (spring cereal)				
moderate	0	14	4 (7-17%)	7 (11-18%)
high	0	2	5 (5-14%)	2 (10-34%)
at ZCK 31 or later				
moderate	0	8	2 (6-18%)	2 (11-18%)
high	0	1	3 (5-10%)	3 (14-20%)

range of experimental standard error = 0.91-6.25%

Table 3

Effect of weed population on yield at recommended rates

Moderate to high populations of broad-leaf weed present

Weed population	Yield < untreated	Yield = untreated	Yield > untreated at p = 5%	p = 1%	proportion of sites showing increase
moderate	0	31	7	12	1:2
high	0	3	8	8	5:1

Table 4

Effect of product rate of use on yield

Moderate to high populations of broad-leaf weed present

Product rate of use r = recommended rate	Yield< untreated	Yield = untreated	Yield>untreated at p = 5%	p = 1%	score for weed control
	number of comparisons				
rx1	0	34	15	20	9-10
rx1½	0	21	11	21	9-10
rx2	0	32	11	12	9-10
rx3	0	1	0	0	9-10

At one very weedy site where a hand weeded treatment was included, this and herbicide treatments achieved similar yield increases over untreated, (Table 5).

Table 5

Comparison of herbicide treatment and hand weeding in the presence of a high population of Sinapis arvensis

treatment (recommended rate)	Yield as percentage of untreated control				Yield as percentage of hand weeded			
	stage at application				stage at application			
	ZCK 11	ZCK 13	ZCK 14	ZCK 15	ZCK 11	ZCK 13	ZCK 14	ZCK 15
	percentage yield				percentage yield			
mecoprop	132.8**	129.1**	126.3**	134.1**	102.8	100.0	97.8	103.9
MCPA				131.1**				105.5
hand weeded				129.1**				100
unsprayed				100				77.4**
standard error				5.2				4.0
significant difference								
p = 5%*				14.3				11.1
p = 1%**				18.9				14.6

DISCUSSION

In the interests of timely removal of weed competition and to minimise the risk of crop loss, late spraying if at all avoidable, is clearly undesirable. Nevertheless, employed as an experimental technique, applications at product recommended rates in weed free fields indicate only a limited risk of crop loss. Improved yields may well follow late spraying in weedy fields and even when there is no yield improvement, an easier harvest may justify herbicide application.

In considering their influence upon yield, we can regard herbicides as a means of achieving a crop's full potential. It is the weed that depresses yield, not the herbicide that increases it. This potential is well represented by the yield achieved following the hand weeded treatment included at one site. Strikingly, all herbicide treatments, whether applied late or early enabled the same yield to be attained.

None of the data presented is intended either to represent an extended recommendation for the products tested or to quantify the extent of yield variation that might be experienced in practice. The risks of herbicide spraying can be exaggerated and it is hoped that this paper helps to put herbicide safety and performance in proper perspective. Ultimately the decision if and when to spray remains with the farmer. Certainly, no contravention of P.S.P.S. regulations should be countenanced, but late spraying very weedy fields will often increase yield, would most probably be economically justified and thus form an essential part of the crop protection programme.

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NOTES

WINTER CEREAL TOLERANCE OF AN HYDROXYBENZONITRILE: PHENOXYALKANOIC MIXTURE APPLIED IN THE SPRING UP TO AND BEYOND THE SECOND NODE DETECTABLE GROWTH STAGE

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Summary Trials were carried out to determine winter cereal tolerance of an hydroxybenzonitrile : phenoxyalkanoic mixture (ARD 12/75) applied at growth stages Zdc 13.21 - 31, from Zdc 31 upto and including Zdc 32 and from Zdc 32 upto and including Zdc 33.

The herbicide at twice the recommended rate of use was well tolerated by weed free winter cereals at upto Zdc 32 ("second node detectable growth stage"). Treatment beyond this growth stage was reflected in small but not statistically significant yield losses.

Treatment of weed infested crops of Maris Otter and Maris Huntsman did not give significant yield benefits over untreated. Nevertheless there was a trend towards higher grain yield with early weed removal. Treatment after Zdc 32 gave grain yield levels similar to those of untreated controls.

Resume Des essais ont été effectúes pour déterminer la tolérance des céréales d'hiver à un mélange hydroxybenzonitrile - phenoxyalkanoic (ARD 12/75) appliqué au stade Zdc 13.21 - 31, de Zdc 31 jusqu'à et y compris Zdc 32 et de Zdc 32 jusqu'à et y compris Zdc 33.

L'herbicide, au double de la dose homologuée, a bien été toléré par les céréales d' hiver en l' absence de mauvaises herbes jusqu' au Zdc 32 (le stade de développement où le deuxième noeud est discernable). Des traitements au delà de ce stade de développement ont montré une petite perte de rendement mais les différences n'étaient pas significatives.

Le traitement des cultures de Maris Otter et de Maris Huntsman, infestées par les mauvaises herbes, n'a pas donné d'augmentations significatives de rendement comporativement aux témoins. Néanmoins, il-y avait une tendance vers une récolte de grain plus élevée si les mauvaises herbes sont enlevées au début. Des traitements après Zdc 32 ont donné des récoltes de grains du même ordre que celles des témoins.

INTRODUCTION

The excellent tolerance by cereals of hydroxybenzonitrile : mecoprop ester mixtures at twice the recommended weed control dose applied in the autumn or spring, from Zdc 12 to Zdc 32 has been reported (Horsnail *et al* 1978).

Late growth stage spraying of winter cereals for broad leaved weed control is practiced by many farmers every season and is particularly prevalent following wet but mild winter/early spring conditions. ARD 12/75 (Brittox), containing esters of bromoxynil, ioxynil and mecoprop, has been in full commercial use in the UK for 3 years and offers flexibility to cereal farmers with recommendations for treating winter cereals with safety up to and including Zdc 32. However, late spraying of winter cereals with phenoxyalkanoic herbicides has been reported to cause grain yield reductions (Evans 1974, Evans 1978, Munro 1972, Roebuck 1976, Tottman et al 1974). Recent reports have also been received of yield losses resulting from applications of ARD 12/75 to winter cereals at Zdc 32 (Askew 1979, Makepeace 1980).

This paper summarises winter cereal tolerance data obtained from weed-free and weed-infested crops treated with ARD 12/75 at growth stages up to and beyond Zdc 32 during 1980.

MATERIALS AND METHODS

Compounds used: ARD 12/75 (Brittox):- bromoxynil + ioxynil (as octanoate ester) + mecoprop (as iso-octyl ester) as e.c. - containing 52.5% total ai : standard rate of use 3.5 l/ha.

Site details: 4 small plot replicated trials in commercial crops of winter wheat (2 sites) and winter barley (2 sites) in W. Essex. Three replicates, sprayed with Ongar small plot motorised (wheeled) sideboom precision sprayer, 196 l/ha. Plots 3.0 m x 15.0 m.

Assessments: Crop tolerance:- Plots visually scored by a minimum of 3 assessors for post spray phytotoxic symptoms (using a 0-100% score system, 0 - as per mean of untreated plots with degrees of phytotoxicity assessed in 5% graduations - 100% complete kill). Observations on ear deformity were made before harvest. Grain yields were taken using Claas "Columbus" combine and expressed at a calculated 85% dry matter.

Weed control:- Pre spray species counts using 2 x $\frac{1}{2}m^2$ quadrats/plot visually scored for percentage bulk total weed control prior to harvest.

RESULTS

Results have been summarised according to cereal growth stage (Zdc scale) at time of treatment in table 1.

T_1 - Normal spray timing, 13-15.21-25 up to 31.

T_2 - Advance spray timing, from 31 up to and including 32.

T_3 - Late spray timing, from 32 up to and including 33 and beyond.

The crops of Hobbit and Igri were weed free whilst those of M. Huntsman and M. Otter competed with a moderate infestation of overwintered Stellaria media (20 plants/m^2) and a severe infestation of overwintered Matricaria matricarioides (260 plants/m^2) respectively. Table 2 summarises the weed control achieved with ARD 12/75 applied at the various stages of weed growth.

ARD 12/75 at 7.0 l/ha was well tolerated at all timings. Only transient phytotoxicity expressed as slight leaf margin scorch (max. 5% level) was evident for up to 14 days post spray and there were no noticeable symptoms of ear deformities.

Table 1

Yield response of winter cereals to treatment at different growth stages

Grain yields in tonnes/ha

Crop	Winter Barley			Winter Wheat			Winter Barley			Winter Wheat		
Variety	Maris Otter			Maris Huntsman			Igri			Hobbit		
Major weed (pop/m^2)	Matricaria matricarioides (260)			Stellaria media (20)			Weed free			Weed free		
Application timing	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
Crop growth stage (Zdc)	21-25	75%-31 25%-32	10%-32 90%-33+	21-25	45%-31 55%-32	25%-32 75%-33+	23-27	30%-31 70%-32	50%-33 50%-34+	23-31	80%-31 20%-32	15%-32 85%-33+
ARD 12/75 7.0 l/ha	6.19	5.93	4.83	7.43	6.98	6.72	8.18	7.95	7.15	7.52	7.40	7.12
ARD 12/75 3.5 l/ha	6.63	5.62	5.04	7.69	6.63	7.05	7.75	8.06	7.49	7.05	7.49	6.82
Timing means	6.41	5.78	4.94	7.56	6.81	6.89	7.97	8.01	7.32	7.29	7.44	6.97
Unsprayed control		4.88			7.40			8.16			7.42	
S.E ±		0.60			0.16			0.32			0.83	
L.S.D. between treatment means (5%)		NS			NS			NS			NS	
L.S.D. between timing means (5%)		NS			1.12			NS			NS	
L.S.D. between timing means (1%)		NS			1.57			NS			NS	

Table 2

Susceptibility of Stellaria media and Matricaria matricarioides at different growth stages

Weed control - % control of weed bulk prior to harvest.

Weed species (pop/m^2)	Stellaria media (20)			Matricaria matricarioides (260)		
Application Timing	T_1	T_2	T_3	T_1	T_2	T_3
Weed growth stage at spraying	8-10cm diam in bud	Established in flo.	Established in flo.	5-8cm height 5-8 branches	8-10cm height 8-12 branches	10cm+ height Mature plants
ARD 12/75 7.0 l/ha	100	100	100	93	95	97
ARD 12/75 3.5 l/ha	100	73	70	90	87	87

Winter Barley

Yield differences between treated and untreated barleys at all timings were not statistically significant. Nevertheless, the effect of autumn germinating M. matricarioides on the yield potential of M. Otter is shown between untreated and treated yield levels at timings T_1 and T_2. At timing T_1, weed control was generally comparable between the two doses of ARD 12/75. However there is a trend towards reduced efficacy with more advanced weeds at later timings and control with ARD 12/75 at the 3.5 l/ha rate was inferior to that achieved at the 7.0 l/ha rate. This was reflected in the yield response of M. Otter where the trend for greatest yield increase was achieved at timing T_1. That crop development was unaffected by treatment at timings T_1 and T_2 is shown by comparison between treated and untreated yields of weed free Igri. Comparable yields between untreated and treated weed infested M. Otter were achieved with ARD 12/75 applied at timing T_3, whilst weed free Igri responded with small yield reductions to treatment at this timing.

Winter Wheat

Yield differences between treated and untreated wheats at all timings were not statistically significant. That crop development was unaffected by treatment at all timings, is shown by comparison between treated and untreated yield levels of weed free Hobbit, where comparable yields were achieved even at twice the recommended dose rate of ARD 12/75. Differences in yields of M. Huntsman between treatment timings were significant at the 1% level (timings T_2 and T_3 giving lower yields than T_1). However, this crop competed with a moderate but irregular infestation of S. media. Weed resistance to treatment increased with time and efficacy at timings T_2 and T_3 at the 3.5 l/ha rate of ARD 12/75 and was inferior to that achieved at timing T_1. This probably accounts for the trend towards reduced yields at the later treatment timings.

DISCUSSION

Early removal of autumn germinating weeds is essential for optimising yield potentials of winter cereals. Trials with weed infested crops show that a delay in herbicide treatment is generally reflected by reduced yield benefits. Applications of ARD 12/75 at up to and including Zdc 32 ("up to the 2nd node detectable") gave yield increases over untreated, but the optimum benefits were seen with applications made prior to the "noding growth stages". Up to this stage of crop development, weed competition, particularly from M. matricarioides, had apparently not seriously impaired grain yield potential. Winter barley responded with higher yield increases than winter wheat, although this is possibly a function of weed infestation levels. However, weed (S. media) removal from winter wheat prior to the "noding" stage gave significantly higher yields than treatment at later growth stages.

ARD 12/75 at twice the recommended rate of use, was well tolerated by winter barley and winter wheat when treated at up to the "second node detectable" growth stage. Treatment beyond this growth stage was generally reflected in small but consistent yield reductions in weed free crops.

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NOTES

POST-EMERGENCE CONTROL OF AVENA FATUA & AGROPYRON REPENS IN PEAS USING ALLOXYDIM-SODIUM & NP 55

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Summary Replicated experiments were carried out to assess materials for post-emergence control of *Avena fatua* and *Agropyron repens*, in vining peas for processing. In 1979, alloxydim-sodium was compared with approved material diclofop-methyl, and both gave excellent control of *A. fatua*. Alloxydim-sodium also effectively suppressed *A.repens* in two experiments. In 1980, coded material NP 55 was compared with alloxydim-sodium for control of *A. fatua* and *A. repens*. In a dry season, conditions for growth were poor when treatments were applied, and alloxydim-sodium did not achieve the same level of control as in previous years. NP 55 was more effective. Split applications of alloxydim-sodium, or NP 55, were little more effective in controlling *A. repens* than a single application. The addition of adjuvant oil to alloxydim-sodium improved control of *A. repens*, but appeared less safe to the crop. NP 55 appeared to be more active than alloxydim-sodium and more selective on peas.

Résumé On a fait des essais répetés pour évaluer les effets des traitements pour le contrôle en post-levée de *Avena fatua* et de *Agropyron repens* sur une culture de petits-pois recoltés mécaniquement et conditionnés. En 1979, alloxydim-sodium a été comparé avec une substance approuvée, diclofop-methyl, et tous les deux ont donné un excellent contrôle de *A. fatua*. Alloxydim-sodium a aussi efficacement éliminé *A. fatua* dans deux essais. En 1980, une substance sous le code NP 55 a été comparée avec alloxydim-sodium pour le contrôle de *A. fatua* et de *A. repens*. Au cours d'une saison sèche, les conditions de croissance, quand les traitements ont été appliqués, se sont révélées mauvaises, et alloxydim-sodium n' a pas atteint le même niveau de contrôle qu'il avait atteint au cours des années précédentes. NP 55 s'est avéré plus efficace. Des applications séparées de alloxydim-sodium ou de NP 55 n'ont pas été plus efficace qu'une seule application pour le contrôle de *A. repens*. L'addition d'huile adjuvante a alloxydim-sodium a amélioré le contrôle de *A. repens* mais semble moins bien tolérée par la culture. NP 55 se révèle plus actif et plus sélectif qu' alloxydim-sodium aux petit-pois.

INTRODUCTION

The importance of good control of wild oats (*Avena fatua*), and couch (*Agropyron repens*), in peas grown for processing has been shown by Gane (1968). Results of previous work (Knott, 1978), showed alloxydim-sodium applied post-emergence to be effective in controlling *A. fatua* and suppressing *A. repens*. Previously there had been no means of selective post-emergence control of *A. repens* in peas. Therefore further experiments were carried out in 1979.

Initial screening tests at the Weed Research Organisation (Richardson & Parker 1980) showed 2 - (n-ethoxybutyrimidoyl)-5-(2-ethylthiopropyl)-3-hydroxy-2-cyclohexen-1-one, coded NP 55, a compound related to alloxydim-sodium, to have a greater activity on grasses when used post-emergence. Peas exhibited a high degree of tolerance to this new material. In 1980, experiments were carried out by PGRO to evaluate NP 55 and alloxydim-sodium for control of A. fatua and A. repens.

METHOD AND MATERIALS

Randomised, replicated experiments were laid down in commercial crops of vining peas on a range of soil types. Varieties used were Puget, Scout, Sprite, Avola and Hurst's Greenshaft.

In 1979, alloxydim-sodium (75% w/w s.p) was compared with approved material diclofop-methyl (36% w/v e.c. formulation) at sites 1 & 2 to control A. fatua and used to evaluate control of A. repens at sites 5 and 6. Layout was a 5 x 5 Latin square. Weather before and after application was wet, and there was active growth of crop and weeds.

In 1980, randomised block experiments with four replications were laid down at sites 3 and 4 to control A. fatua using alloxydim-sodium and NP 55 (20% w/w e.c. formulation containing 184 g a.i./l). Broad-leaved weeds were controlled with approved post-emergence herbicides, dinoseb-amine or cyanazine + MCPB/MCPA tank mix, applied overall at least 7 days after treatments. Experiments to control A. repens were laid down at sites 7 and 8. Layout was a randomised block with three replications. Where split applications were used, the second treatment was sprayed 7 days later than the first. The addition of adjuvant oil (Actipron) to alloxydim-sodium was also evaluated. At the 1980 sites there was a period of drought preceding spray application, and crop and weeds were not growing actively. Later rainfall was high, and peas grew well tending to compete with the weeds.

Growth stages for crop and weeds, and spray application dates are shown in table 1.

Table 1

Crop, Avena fatua and Agropyron repens growth stages at spray application dates

Site	Spray date	Crop Height cm.	Crop No. expanded leaves	Weed Height cm	Weed Growth stage
Wild oat					
1	1/6/79	7	4	-	4 leaf (50% with 1 tiller)
2	6/6/79	5	4	-	3 leaf (20% 1 or 2 tillers)
3	14/5/80	4	2	-	3 leaf
4	16/5/80	10	5	-	3 leaf, 1 tiller
Couch					
5	2/6/79	16	5	20	4 leaf, 2 tillers
6	1/6/79	30	8 in bud	30	1-3 nodes, 3 or 4 tillers
7	9/5/80	7	4	7	2-3 leaf
8	23/5/80	23	7	13	4 leaf

Materials were applied with a Van der Weij sprayer, at a pressure of 1.7 bar, using Birchmeier cone nozzles delivering 220 l/ha. Plot size was 10 m^2.

Treatment timing was based solely on growth of A. fatua or A. repens. Although the optimum target for A. fatua was at the 2-3 leaf stage, application was late at site 4 to allow for recovery of peas from frost damage.

At harvest, A. fatua was assessed by counting and weighing the plants and panicles per plot. A. repens was assessed by counting the number of live shoots in 0.3 m^2 quadrats placed at the random positions in each plot. The peas were harvested at the green freezing or canning stage of maturity, and threshed using a plot viner. Pea yields were measured, and maturity recorded using a tenderometer.

Samples of peas from plots treated with alloxydim-sodium, alloxydim-sodium + oil and NP 55 at different sites were frozen or canned, and the produce assessed for possible taints by the Campden Food Preservation Research Association.

RESULTS

Crop assessments There was little visible damage to the peas from treatments used in the A. fatua experiments at sites 1, 2, 3 and 4. Some necrotic patches were seen on lower leaves on plots treated with alloxydim-sodium. Damage from NP 55 even at the 0.86 kg a.i./ha rate was negligible. At sites 5 & 6 peas treated with the 4.0 kg ai/ha rate of alloxydim-sodium showed severe initial damage in the form of necrosis of lower leaves, chlorosis and stunting. However, these effects were temporary and grew out by harvest. NP 55 appeared to be slightly safer than alloxydim-sodium in terms of visual crop effects at sites 7 and 8. Alloxydim-sodium at 3.0 kg a.i./ha + oil gave an unacceptable level of damage in the form of severe scorch, chlorosis and stunting at site 7, but the crop eventually recovered. Assessments of pea leaf wax using the crystal violet test, (Amsden & Lewins, 1966, King, 1978) seven days after application of treatments, indicated that alloxydim-sodium reduced wax more than NP 55, and the addition of oil to alloxydim-sodium increased this effect.

Avena fatua & Agropyron repens Assessment of A. fatua and A. repens plants at several stages in 1980 indicated that alloxydim-sodium achieved a slower kill than NP 55. Symptoms were similar for both materials, and the grasses suffered from stunting, chlorosis and later necrosis, and also root inhibition. Leaves of plants treated with alloxydim-sodium assumed a dark reddish colouration.

Yield of peas & control of Avena fatua The results of crop yields and A. fatua control for the 1979 and 1980 experiments are presented in tables 2 and 3 respectively.

Yields of treated plots were better than untreated at sites 1 and 2, but increases were not statistically significant in spite of excellent control of A. fatua from all rates of alloxydim-sodium, and from the normal recommended rate of diclofop-methyl. At site 3, where the infestation of A. fatua was high, all treatments gave significantly greater yields than untreated plots, with the exception of the highest rate of NP 55. Control of A. fatua was very good for all treatments. At site 4, however, control of A. fatua was excellent for NP 55, but alloxydim-sodium gave poor control at the normal recommended rate of 0.94 kg a.i./ha.

Table 2

Yield of peas & percentage reduction in number & weight of A. fatua plants & number of panicles 1979

Material	Rate kg a.i./ha	% reduction in wild oats at harvest No. plants		Wt. plants		No. panicles		Yield as % of untreated	
	Site:	1	2	1	2	1	2	1	2
alloxydim-sodium	0.75	100	90	100	95	100	91	111	106
" "	1.00	99	96	100	99	100	100	111	105
" "	2.00	100	100	100	100	100	100	102	113
diclofop-methyl	1.25	87	95	99	98	97	97	103	107
Significance @ P = 0.05		SD	SD	SD	SD	SD	SD	NS	SD
LSD @ P = 0.05		29.2	21.3	36.3	10.7	31.9	31.5	-	9.8
S.E. as % of general mean		27.4	20.3	33.1	9.9	29.2	29.4	10.4	6.7
Yield t/ha of untreated		-	-	-	-	-	-	7.7	6.8
No./m^2 A. fatua or panicles on untreated		4	6	-	-	7	7		
Wt. t/ha A. fatua plants on untreated		-	-	2.3	7.4	-	-		

Table 3

Percentage reduction in number & weight of A. fatua plants & number of panicles & yield of peas 1980

Material	Rate kg a.i./ha	% reduction in wild oats at harvest No. plants		Wt. plants		No. panicles		Yield as % of untreated	
	Site:	3	4	3	4	3	4	3	4
alloxydim-sodium	0.94	81	37	93	36	91	43	131	112
" "	1.88	95	74	98	74	99	70	137	99
NP 55	0.33	97	98	99	99	100	99	147	97
"	0.43	99	99	100	99	100	98	129	123
"	0.86	100	100	100	100	100	100	124	114
Significance @ P = 0.05		SD	SD	SD	SD	SD	SD	SD	NS
LSD @ P = 0.05		25.2	54.0	20.9	62.4	27.8	56.2	27.3	-
S.E. as % of general mean		21.3	52.9	17.0	60.6	22.6	54.5	14.2	22.9
Yield t/ha of untreated		-	-	-	-	-	-	3.7	6.3
No./m^2 A. fatua or panicles on untreated		33	5	-	-	10	6		
Wt. t/ha A. fatua plants on untreated		-	-	8.6	1.9	-	-		

Yield of peas & control of Agropyron repens The results of pea yields and reduction of live A. repens shoots at harvest for the 1979 and 1980 experiments appear in tables 4 and 5.

Table 4

Percentage reduction in number of live *A. repens* shoots at harvest & yield of peas 1979

Material	Rate kg a.i./ha	% reduction in no. *A. repens* shoots at harvest		Yield as % of untreated	
	Site:	5	6	5	6
alloxydim-sodium	1.00	98	77	122	116
" "	1.50	100	82	115	120
" "	2.00	100	98	109	108
" "	4.00	100	99	109	108
Significance @ P = 0.05		SD	SD	SD	SD
LSD @ P = 0.05		17.5	15.3	3.9	18.1
S.E. as % of general mean		15.9	15.6	9.5	11.8
Yield t/ha of untreated		-	-	4.1	6.1
No./m^2 *A. repens* shoots on untreated		92	202		

Table 5

Percentage reduction in number of live *A. repens* shoots at harvest & yield of peas 1980

Material	Rate kg a.i./ha	% reduction in no. *A. repens* shoots at harvest		Yield as % of untreated	
	Site:	7	8	7	8
alloxydim-sodium	1.50	59	78	106	100
" "	3.00	79	91	112	100
" " + oil	1.50 + 2.51 prod.	70	72	112	100
" " "	3.00 + 5.01 prod.	90	95	105	94
" " split	0.94 & 0.94	69	88	109	92
" " "	1.88 & 1.88	91	95	105	94
NP 55	0.57	72	91	105	95
"	1.15	89	97	97	93
" split	0.29 & 0.29	66	96	113	93
" "	0.57 & 0.57	86	99	114	93
Significance @ P = 0.05		SD	SD	NS	NS
LSD @ P = 0.05		12.2	17.3	-	-
S.E. as % of general mean		15.9	19.2	11.9	10.8
Yield t/ha of untreated		-	-	7.5	8.5
No./m^2 *A. repens* shoots on untreated		133	123	-	-

At site 5, treated plots yielded significantly better than untreated plots, with the exception of the highest rate of 4 kg a.i./ha. Control of *A. repens* was nearly 100% and there was no significant difference between treatments. At site 6, where peas were suppressed by the *A. repens* before materials were sprayed, treated plots yielded better than untreated plots but only significantly so for alloxydim-sodium at 1.5 kg a.i./ha. Yield of peas was similar for all treatments at sites 7 and 8, and none differed significantly from the untreated plots. NP 55 gave better control of *A. repens* than alloxydim-sodium at both sites.

Split applications of alloxydim-sodium and NP 55 performed slightly better than single applications but not significantly so.

The addition of oil to alloxydim-sodium only appeared to improve control at site 7.

Maturity Maturity of the peas as recorded by tenderometer readings, showed no significant difference between treated and untreated plots for any of the 8 experiments.

Produce Quality No taints have been found in canned and frozen samples of peas from plots treated with alloxydim-sodium, and the material has now been given clearance for use on peas for processing. Samples treated with NP 55, and alloxydim-sodium + oil, are being assessed by Campden Food Preservation Research Association.

DISCUSSION

These results show that alloxydim-sodium is capable of giving excellent control of *A. fatua* at rates of 0.94 kg a.i./ha and above, where conditions of active growth occur as in 1979 and 1978. Control was reduced at site 4 in 1980 where the *A. fatua* had been checked by frost and drought. Alloxydim-sodium is selective in the pea crop at twice the 0.94 kg a.i./ha rate. Alloxydim-sodium achieved good suppression of *A. repens* at all rates used in the 1979 experiments, but visual crop damage was seen from the 4 kg a.i./ha rate and in view of the excellent weed control it is possible that yields were slightly reduced at this rate. In 1980 control of *A. repens* with alloxydim-sodium was less effective at site 7, where the material was applied under dry, poor growing conditions.

The addition of oil to alloxydim-sodium increased performance of the herbicide at site 7, but also induced more crop damage which was not acceptable.

Control of *A. repens* was marginally better using split applications of alloxydim-sodium or NP 55 instead of a single application but not significantly so. In practical terms, since the pea crop has a short growing season there is often insufficient time and number of suitable spraying days for a farmer to apply two treatments for *A. repens*, and possibly a post-emergence broad-leaved weed herbicide as well 7 days later.

Screening tests carried out at PGRO for susceptibility to alloxydim-sodium for a wide range of vining and dried pea varieties, have shown that, with the exception of Vedette, most are tolerant to the material.

The 1980 experiments indicate that NP 55 was slightly quicker to take effect on grass weeds, and appeared to have a wide range of crop safety, even at the 1.15 kg a.i./ha rate, in terms of visible crop damage. NP 55 was more active and gave better control of *A. fatua* at 0.33 kg a.i./ha and *A. repens* at 0.57 kg a.i./ha compared with rates of 0.94 and 1.50 kg a.i./ha in the experiments.

In 1980 clearance was given by the Pesticides Safety Precautions Scheme for use of alloxydim-sodium on a limited commercial acreage. Label recommendations for post-emergence application in vining peas were for rates of 0.94 kg a.i./ha to control *A. fatua* and 1.50 kg a.i./ha for *A. repens*.

It is hoped that this preliminary work with NP 55 for control of grass weeds in peas, and with alloxydim-sodium + oil for control of *A. repens*, will be continued.

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NOTES

ALLOXYDIM-SODIUM POTENTIAL IN VEGETABLE CROPS

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Summary Alloxydim-sodium has been shown to control annual and perennial grasses including *Avena* spp., volunteer cereal and *Agropyron repens* in a wide range of vegetable crops. All vegetable crops tested showed a high degree of tolerance to applications of alloxydim-sodium at doses up to 3.75 kg a.i./ha.

No yield depressions from applications of alloxydim-sodium have been detected in weed-free crops and no significant taints have been detected in canned and quick-frozen crops.

Resume L'alloxydim sodium a supprimé les graminées annuelles et vivaces, *Avena* spp, *Agropyron repens* et les repousses des céréales y compris, dans une large gamme de végétaux.

Toutes les cultures des végétaux experimentées ont tres bien toléré l'alloxydim sodium au dose de 3.75 m.a./ha.

Les rendements ne diminuaient pas après on a traité les culture non infestées par les adventices auec l'alloxydim sodium, et il n' y avent pas de mauvais goût dans les cultures êngelées ou mises en boîte.

INTRODUCTION

The activity of alloxydim-sodium for control of annual and perennial grass weeds in broad-leaved crops has been previously reported, Formigoni and Hirono, 1977; Ingram, *et al*, 1978; Iwataki and Hirono, 1978; Quere, *et al*, 1977; Salembier, *et al*, 1977 and Vernie *et al*, 1977.

Alloxydim-sodium has shown a good potential for use in vegetable crops Knott, 1978 and Pujol, *et al*, 1979, and this paper summarises 2½ years of May & Baker and co-operator trials carried out in vegetable crops in the U.K. for the control of *Agropyron repens*, *Avena* spp. and volunteer cereals.

METHOD AND MATERIALS

Methods

1. Application (a) Small plots. Treatments applied with a self-propelled, precision small plot sprayer at the following volume rates: 1978 - 235 l/ha; 1979 - 240 l/ha and 1980 - 204 l/ha at a pressure of 2.07 bars.

(b) User trials. Treatments applied with farm machinery at a target volume rate of 200 l/ha. Treatments were fitted into grower's weed and pest control programmes.

2. Layout

(a) Small plots. Randomised block design with 3 replicates, plot sizes were usually 2.5m x 10m.

(b) User trials. 1-3 treatments applied in 0.5-1 ha. blocks.

3. Assessments

(a) Crop tolerance. Visual assessment of crop condition was made using a 0-100% system in 2.5% increments where 0 = complete tolerance and 100 = complete destruction. Each treatment is compared to the unsprayed control considered as score zero, thus crop damage is indicated as a negative score and crop improvement as a positive score.

(b) Harvest data

(i) Dried peas and field beans: A cut of 1.83m x 10m per plot was made with a Claas "Colombus" plot combine.

(ii) Onions. Autumn and spring sown. A known row length was hand lifted recording, total weight and number of onions.

(iii) Cabbage. Marketable samples were cut from each plot at three sequential timings, recording total weight and number of cabbages.

(iv) Spring greens. A known row length was cut recording total weight and number of plants.

4. Weed control

a) Small plot trials.

Quadrat counts of 2 x 0.5m^2 per plot recording number and height of all weeds present.

b) User trials.

Generally an appropriate number of fixed quadrats to give a minimum count of 500 target weeds were established. Pre- and post-treatment counts of grass weeds were made.

5. Taint tests

Taint tests were carried out by The Campden Food Preservation Research Association, Chipping Campden, Gloucester.

Table 1
Crops and cultivars tested

Calabrese	Brussel sprouts	Cabbage	Cauliflower	Spring Greens
Gem	Citadel	Primo	Nevada	Pixie
	Linette	Celtic	Flora Blanca	Hardy Offenham
	Jade E	1st June		
	Valiant	Stonehead		
		January King		

Table 1 (continued)

Carrots	Potatoes	Swedes
Amsterdam Forcing (Asmer Super Sprite)	Pentland Javelin	Wilhemsburger
Chantenay (Cluseed New Model)	Ulster Sceptre	Western perfection
Nantes (Nantes 20)	Desiree	Doon major
Autumn King (Vita longa and Flakko)	King Edward	Laurentian
Berlicum (Berjo)	Pentland Crown	Harriet Field
	Record	Rot-obura
	Maris Piper	Rot-otofti
	Cara	Monkwood
		Balmoral

Turnip	Leeks	Peas*
Green Top Scotch	Splendid	Scout
The Bruce		Puget
Purple Top Major		Dark Skin Perfection
		Maro
		Bertie
		Vedette

Onions

Overwintered	Early	Maincrop	Salad
Senshyu	Rocket	Hyduro	White Lisbon
Imi	Augusta	Rijnsburger Robusta	
Presto		Rijnsburger Rivalto	

Broad Beans	Dwarf Beans	Field Beans
Beryl	Dark Seeded Provider	Maris Bead
	Cascade	
	Chicobel	

* Peas These are standard cvs. Over 25 other cvs. have been tested and have shown tolerance.

Materials

Alloxydim-sodium	75% w/w S.P.	'Clout'
Phenmedipham	11.4% w/c E.C.	"Betanal E"

RESULTS AND DISCUSSION

The following results and discussion summarise the work carried out in vegetable crops in the UK from 1977-78 winter crops to 1980 spring crops.

Table 2

Suppression of *Agropyron repens* by alloxydim-Na 1.88 kg a.i./ha

Crop	No. of trials	Mean % control of couch* bulk	Assessment weeks post spray
Brassicae	3	94	7
Carrots	1	97	9
Onions	5	70	5
Peas	9	93	6
Potatoes	4	97	5

* Couch majority *Agropyron repens* some sites *Ag. repens* and *Agrostis gigantea*.

Table 3

Control of annual grass species by alloxydim-Na 0.94 kg a.i./ha

Weed	Crop	No. of trials	Mean % control of weed
Avena spp	Peas	8	90
	Field beans	1	93
Volunteer cereal	Brassicae*	2	86
	Onion*	4	78
	Peas	1	93

* Late summer/autumn treatment

1. Weed control

(a) *Agropyron repens* (Table 2). Good suppression of *A. repens* was obtained with alloxydim-Na 1.88 kg a.i./ha when sprayed at any stage up to shoot elongation. Regrowth of *A. repens* may occur after 10-12 weeks should conditions favour it. In less competitive crops regrowth is quicker, in high competitive crops such as potatoes, regrowth is less of a problem. However, all crops benefited from the "releasing effect" resulting from the suppression of couch grasses, and such suppression may make harvesting easier in badly infested root crops as well as improving the situation for following crops.

(b) Annual grasses (Table 3). Good control of *Avena* spp and volunteer cereals was obtained from a spring application of alloxydim-Na 0.94 kg a.i./ha when the target weeds were at Zadoks 12-21.

Late summer/autumn treatment of overwintered crops for the control of volunteer cereals with alloxydim-Na 0.94 kg a.i./ha did not show such high levels of control as spring treatment. However, alloxydim-Na 1.5 kg a.i./ha has been shown to give improved control of volunteer cereals in Japanese onions and spring greens. Later applications of alloxydim-Na when the annual grasses were beginning to tiller were not so successful. Good control may still be possible if the plants are actively growing but spraying beyond the Zadoks 22 growth stage is not to be recommended.

Alloxydim-Na has also been shown to have activity against *Agrostis gigantea* (black bent), *Alopecurus myosuroides* (blackgrass), *Alopecurus pratensis* (meadow foxtail), *Bromus sterilis* (sterile brome), *Dactylis glomerata* (cocksfoot), *Phleum pratense* (timothy), *Lolium perenne* (ryegrass) and *Poa trivialis* (rough stalked meadow grass) whilst *Poa annual* (annual meadow grass) is completely resistant.

Table 4

Summary of crop tolerance to alloxydim-Na

Highest crop reduction recorded at any one time throughout evaluation period

Scored on 0-100% system

Material	Dose kg a.i./ha	Calabrese	Brussel Sprouts		Cabbage - Summer			Cabbage - Winter**	Cauliflower	Spring greens	Carrots		Potatoes		Swedes	Turnips	Leeks	Onions - spring sown bulb		Onions - autumn sown bulb	Onions - salad	Peas	Beans - Broad	Beans - Dwarf Green	Beans - Field
Alloxydim-Na	0.94	0	-	0	-	-	-	-	0	0	0	0	-	0	0	0	-	2.0	-	0	-	-	0	0	-
	1.50	-	-	-	2.0	0	-	-	-	-	-	-	2.0	-	2.0	2.0	-	-	1.1	-	-	-	-	-	1.0
	1.88	5.0	1.5	5.0	-	0	0	0	10	0	0	0	2.5	0	5.0	-	2.0*	2.5	1.1	0	3.0*	2.0	0	0	1.5
	3.0	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3.75	10.0	-	-	2.5	0	-	-	10	-	-	0	-	-	2.0	-	2.0	-	6.8	-	-	2.5	-	-	-
Year		80	79	80	78	79	80	80	80	79/80	79	80	78	80	80	80	-	78	79	79/80	-	78	80	80	78
Crop growth stage at spray		3 lvs	6-10 lvs	2 lvs	6-8 lvs	10-16 lvs	2-5 lvs	2-5 lvs	1 L 1 L	2-4 lvs	4-10 lvs	1-2 lvs	80% emergence	100%	4-6 lvs	4-6 lvs	2 lvs	2-3 lvs	2-6 lvs	2-4 lvs	2 lvs	3-6 lvs	5 lvs	2-3 lvs	6 lvs

* Treatment with alloxydim-Na followed by ioxynil octanoate 700 gms a.i./ha.

** Autumn treatment.

Table 5

Scores for crop damage (0-100% system) varietal tolerance screen 1980

Material	Dose kg a.i./ha	Mangels Wintergold	Fodder beet Monorosa	Red beet Detroit Globe	Swede Western Perfection	Brussel Sprout Citadel	Calabrese Italian Sprouting	Cabbage Greyhound	Cabbage January King	Cabbage Primo	Potatoes Pentland Javelin	Potatoes Wilja	Potatoes Maris Peer	Potatoes Desiree	Potatoes Arran Pilot	Potatoes Maris Piper	Potatoes King Edward
		CHENOPODIACEAE			BRASSICAE						SOLANACEAE						
Alloxydim-Na	7	0	0	0	0	0	0	0	0	0	1.25	0	1.25	0	1.25	1.25	0
	14	0	0	2.5	0	0	0	0	0	0	0	0	0	0	0	1.25	1.25
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alloxydim-Na	7	0	2.5	2.5	1.25	0	0	0	0	0.6	2.5	3.75	2.5	0	1.25	1.25	1.25
	14	0	0	11.23	3.75	1.25	2.5	0	0	0	1.25	0	1.25	0	2.5	0	1.25
	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alloxydim-Na	7	5.6	10	12.5	15	0	12.5	3.75	0	1.25	7.5	10.0	3.75	1.25	2.5	0	1.25
	14	8.1	10	22.5	10	0	8.75	0	1.25	7.5	1.25	0	0	0	2.5	0	0
	28	0	0	0	0	0	1.25	0	0	0	0	0	0	0	0	0	0
Alloxydim-Na	7	0	0	1.9	0.6	-	-	-	-	-	-	-	-	-	-	-	-
+	14	1.25	0	5	4.4	-	-	-	-	-	-	-	-	-	-	-	-
phenmedipham	28	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-
Growth stage at spraying		4-7 lvs	4-9 lvs	4-7 lvs	5-8 lvs	6-8lvs Trans-plants	3-6 lvs	4-7 lvs	3-5 lvs	3-6 lvs	14-20"	14-18"	14-18"	6-12"	16-20"	16-20"	15-20"

All potatoes 100% emergence

2. Crop tolerance (Tables 4 and 5)

Vegetable crops were shown to be highly tolerant to alloxydim-Na at doses up to 3.75 kg a.i./ha. Where damage occurred it was only transitory. This is shown in the scores from the varietal tolerance screen where the slight damage shown at 7 and 14 days post-spray had completely disappeared at the 28 day assessment. On all crops with the exception of Red beet, no score above 10% damage either as phytotoxicity or crop bulk reduction was recorded over 2½ year's work.

Crop damage was usually as a crop bulk reduction. Where phytotoxicity was observed it was as a slight margin scorch to the crop leaves. It is worth noting that where damage was observed crops were generally at a very young stage when sprayed. Overwintered onions sprayed in the spring showed persistent symptoms of dewaxing but no check to growth. When sprayed in the autumn at the 1-2 leaf stage no damage was noted.

Table 6

Harvest yields obtained from 5 crops expressed as % of unsprayed control

Material	Dose kg a.i./ha	Japanese Onions		Spring Greens		Drying Peas		Field Beans	Summer Cabbage		
		**	**			**					
	Site	1	2	1	2	1	2		1	2	3
Alloxydim Na	0.94	98	86	268*	321*	98	123	106	-	-	-**
	1.88	95	91	282*	315*	89	166*	97	105	240*	82
Unsprayed Yield		37 t/ha	51 t/ha	7.8 t/ha	5.6 t/ha	2.19 t/ha	1.57 t/ha	5.32 t/ha	8.8 t/ha	2.68 t/ha	4.3 t/ha
Significance		N/S	N/S			N/S		N/S			N/S

* Treatment is significantly better than unsprayed control at 5% sig. level.

** Weed free sites.

NS = Non significant at 5% level (Analysis of variance).

3. Harvest Yields (Table 6)

Treatments with alloxydim-Na was shown not to depress harvest yields in weed free situations, there was a slight trend for treated crops to give a lower yield than the unsprayed control, this was however non-significant at the 5% significance level.

In crops that had a severe weed infestation (i.e. Spring greens with volunteer barley or Summer cabbage with *Agropyron repens*) a significant yield increase was shown resulting from the removal of weed competition.

4. Taint tests

In all crops tested for taint, either canned (12 tests), or quick frozen

(14 tests), no taints detected were determined to be significant. Crops tested were Broad beans, Brussel sprouts, Calabrese, Carrots, Cauliflowers, Peas and Swedes.

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3,6-DICHLOROPICOLINIC ACID FOR THE CONTROL OF CREEPING THISTLE (CIRSIUM ARVENSE) AND ANNUAL COMPOSITE WEEDS IN VEGETABLE CROPS

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Summary Glasshouse screening trials indicate that 3,6-dichloropicolinic acid at 100-200 g a.e./ha is safe on red beet, sweet corn and brassica crops. Crops of the onion family are also resistant, provided that a suitable growth stage is achieved before treatment. Carrots, peas, dwarf beans and lettuce are severely damaged or killed by 3,6-dichloropicolinic acid.

One years' replicated trials suggest that sequential applications of 100 and 200 g a.e./ha 3,6-dichloropicolinic acid, with a three week interval, offer safe and effective control of Cirsium arvense in sweet corn and brassica crops. Onions may suffer some leaf damage, but this appears temporary, provided that they are not treated before the 2 true leaf stage with 100 g a.e./ha, or the 3-4 true leaf stage with 200 g a.e./ha. A single application of 100 g a.e./ha is also suitable for control of annual Composite weeds such as Tripleurospermum maritimum or Senecio vulgaris, and for this purpose tank-mixes with other suitable post-emergence herbicides, such as methazole in onions, may be practicable.

Résumé Des essais en serre indiquent que l'acide 3,6-dichloropicolinique à 100-200 g a.e./ha est sans danger pour la betterave rouge, le maïs, et les récoltes crucifères. Certaines cultures parmi la race de l'onion sont aussi résistantes, pourvu qu'une croissance convenable soit obtenue avant le traitement. Les carottes, les pois, les haricots verts et la laitue sont sévérément endommagés ou détruits par l'acide 3,6-dichloropicolinique.

Des essais répétés dans une année suggèrent que des applications en série de 100 et 200 g a.e./ha de l'acide 3,6-dichloropicolinique à une intervalle de trois semaines, offerent sans danger un contrôle efficace de Cirsium arvense pour le maïs et les cultures de la famille des crucifères. Les feuilles des onions peuvent être endommagées, mais cela apparaît être temporaire, pourvu qu'elles ne soient pas traitées avant le stage de 2 vraies feuilles avec 100 g a.e./ha ou au stage de 3-4 vraies feuilles avec 200 g a.e./ha Une simple application de 100 g a.e./ha est aussi convenable pour le contrôle des herbes mauvaises annuelles composées telles que Tripleurospermum maritimum ou Senecio vulgaris, et dans ce but des mélanges avec d'autres herbicides, comme le methazole pour les onions, pourraient être efficaces.

INTRODUCTION

3,6-dichloropicolinic acid was first developed, in mixture with other herbicides, for broad-leaved weed control in cereals (Brown and Uprichard, 1976). Its activity against perennial weed species such as Cirsium arvense was first reported by Keys (1975). Following reports of selectivity in sugar beet (Vernie et al, 1977), a formulation of 3,6-dichloropicolinic acid alone (FORMAT) was developed in the United Kingdom for control of both annual broad-leaved weeds and C. arvense in this crop (Gilchrist and Lake, 1978). This use was later extended to other crops of the beet family, including red beet.

As both annual and perennial composite weeds are a problem in many other vegetable crops in the U.K., two glasshouse screens were carried out to identify other crops in which 3,6-dichloropicolinic acid was selective. A programme of field trials was then initiated on tolerant crops.

METHOD AND MATERIALS

The standard commercial formulation of 3,6-dichloropicolinic acid, containing 100 g a.e./litre, was used in all trials. Other herbicides used were standard commercial formulations.

A primary screen was first carried out in 1979 on a range of vegetable crops. Further screening, including investigations of dose rate and timing, were then carried out in early 1980. Crops under test were grown in John Innes No.1 compost in 14 cm pots to the appropriate growth stage, and treated with 3,6-dichloropicolinic acid at the desired dose rate. Each treatment was replicated twice. Following treatment, regular observations were made of crop damage for a period of two months. At all times, pots were kept in a glasshouse at a constant temperature of 16°C, and watered as necessary. Supplementary lighting was provided to give a day length of 12 hours.

In 1980, a programme of field trials was also commenced, consisting of three trials each on cabbage, cauliflower, brussel sprouts and sweet corn/maize, and four trials on spring-sown bulb onions. All trials were of randomised block design, with three replicates and a plot size of 15-30 m^2. At each site, various dose rates of 3,6-dichloropicolinic acid were tested at two or three times of application. Sequential applications were also tested, as were tank-mixes with methazole on onions.

In both glasshouse screens and field trials, treatments were applied with a Van der Weij propane sprayer using Delavan FJ 14 fan-jets and a pressure of 2.0 bars to give a spray volume of 220 l/ha.

In the glasshouse screens, crop damage was assessed visually on a percent basis at regular intervals. In field trials, a percent visual assessment of crop damage was made 1-2 weeks and 3-5 weeks after each time of treatment, and control of weeds was assessed 3-4 weeks after the final treatment at each site. Although it is intended to take field trials to yield, no data is available at the time of writing.

Table 1

Field trials - site details

Location	*	Crop	Cultivar	Planting date
Cottenham, Cambs.	Dr	Cabbage	Hidena	8.4.80
Woodborough, Notts.	Tr	Cabbage	Hispi	31.5.80
Bicker, Lincs.	Dr	Cabbage	Stonehead	6.5.80
Pershore, Worcs.	Tr	Brussel sprouts	Rampart	31.5.80
Northill, Beds.	Dr	Brussel sprouts	Valiant	17.4.80
Holbeach, Lincs.	Dr	Brussel sprouts	Valiant	14.4.80
Pershore, Worcs.	Tr	Cauliflower	Nevada	1.7.80
Kirton, Lincs.	Tr	Cauliflower	Elgon	5.6.80
Bicker, Lincs.	Tr	Cauliflower	Nevada	23.5.80
Fransham, Norfolk	Dr	Sweet corn	Northern Belle	30.4.80
Woolpit, Suffolk	Dr	Maize	Caldera 535	6.5.80
Brooksby, Leics.	Dr	Maize	Fronica	29.4.80
Cottenham, Cambs.	Dr	Bulb onions	Hygro	6.4.80
Pinchbeck, Lincs.	Dr	Bulb onions	Robusta	2.4.80
Pinchbeck, Lincs.	Dr	Bulb onions	Robusta	3.4.80
Biggleswade, Beds.	Dr	Bulb onions	Sublima	3.5.80

* Dr = Drilled, Tr = Transplanted

RESULTS

Table 2

Primary screen - percent damage from 3,6-dichloropicolinic acid

Crop	Growth stage at treatment	100 g a.e./ha 1 wk	100 g a.e./ha 4 wks	200 g a.e./ha 1 wk	200 g a.e./ha 4 wks
Sugar beet	Cotyledon	2	0	5	2
Red beet	Cotyledon	0	0	0	0
Cabbage	Cotyledon	2	0	5	2
Cauliflower	Cotyledon	5	2	10	5
Brussel sprouts	Cotyledon	5	10	10	15
Sweet corn	1 true leaf	2	5	5	5
Onion	1 true leaf	15	10	30	25
Carrot	2 true leaf	80	90	90	95
Pea	2 true leaf	10	98	15	100
Dwarf bean	2 true leaf	15	70	20	80
Lettuce	Cotyledon	90	100	95	100

Sugar beet, brassicæ and sweet corn all suffered slight epinasty following treatment with 3,6-dichloropicolinic acid. In brassicae, rugosity of the leaf surface was also noted. In most cases these effects were minor and soon outgrown, although more persistent in brussel sprouts.

Onion exhibited leaf twisting and, at 200 g a.e./ha, some prostration. Symptoms persisted for 4-6 weeks, but some recovery was noted after 8 weeks.

In carrot, pea, dwarf bean and lettuce, 3,6-dichloropicolinic acid caused severe leaf distortion, chlorosis, and ultimately death of a majority of plants.

Table 3

Secondary screen - percent damage from 3,6-dichloropicolinic acid one month after treatment

Growth stage at spraying:		1 true leaf			2 true leaf			3 true leaf		
Dose rate (g a.e./ha):		100	200	400	100	200	400	100	200	400
Sweet corn	J.I. Hybrid	5	5	90	2	2	5	2	2	2
Cabbage	Decema	0	0	2	0	2	2	0	2	2
Cabbage	Derby Day	0	0	2	0	5	5	2	5	8
Cabbage	April	2	5	8	3	3	8	2	2	2
Spring greens	Durham Early	5	8	12	2	5	8	5	8	12
Cauliflower	Barrier Reef	0	2	3	0	0	5	0	2	5
Cauliflower	Elgon	0	0	5	0	0	2	0	0	2
Cauliflower	Nevada	0	0	0	0	0	0	0	0	2
Brussel sprouts	Fortress	5	5	5	5	5	8	2	2	10
Brussel sprouts	Citadel	3	8	10	5	8	12	12	15	15
Turnip	Golden Ball	20	40	60	10	20	25	2	5	5
Swede	Ruta Øtofte	0	0	0	0	2	3	0	2	2
Over-wintered bulb onion	Senshyu	10	15	25	2	5	20	0	0	20
Spring-sown onion	Wijbo	12	12	15	0	2	5	0	0	5
Salad onions	White Lisbon	5	5	8	2	2	5	0	0	10
Leek	Baton	10	5	8	0	0	0	0	0	15
Leek	Musselburgh	5	8	8	0	2	2	2	2	5

Sweet corn suffered only slight epinasty and chlorosis from 3,6-dichloropicolinic acid, except when 400 g a.e./ha was applied at the 1 leaf stage, which caused leaf scorch and eventual death.

Hearted cabbage, cauliflower and swede were little affected, although slight petiole elongation occurred at higher dose rates. Rather more petiole elongation and some epinasty were noted in spring greens and brussel sprouts, and turnip was seriously affected, with petiole elongation and twisting producing a "straggling" effect, coupled with a general reduction in vigour and growth.

Bulb onions suffered leaf twisting and prostration when treated at the 1 true leaf stage, but later appeared resistant to doses up to 200 g a.e./ha. The winter-sown variety Senshyu was somewhat more affected than the spring variety Wijbo. Similar effects were noted in salad onions and leeks, but to a lesser degree.

In field trials (see Table 4) 1-2 weeks after treatment with 3,6-dichloropicolinic acid, sweet corn, maize, drilled cabbage and drilled brussel sprouts all exhibited occasional slight epinasty at some sites. In all cases, symptoms were outgrown four weeks after spraying. Transplanted brassicae showed no symptoms of damage at any time.

Table 4

Field trials - mean percent crop damage from 3,6-dichloropicolinic acid after 1-2 weeks

Dose rate (g a.e./ha) Time 1	Time 2	Time 3	Sweetcorn/ maize	Cabbage (drilled)	Brussel sprouts (drilled	Cabbage (transpl.)	Brussel sprouts (transpl.)	Cauliflower (transpl.)
100	-	-	0.2	0.3	0	-	-	-
200	-	-	0.4	0	0.3	-	-	-
400	-	-	0	0.3	0.3	-	-	-
-	100	-	0	0	0	0	0	0
-	200	-	0.2	0	0	0	0	0
-	400	-	0.8	0	0	0	0	0
-	-	200	0.6	0	0	0	0	0
-	-	400	0.2	0.3	0	0	0	0
100 +	200	-	1.1	0	0	-	-	-
-	100 +	200	0	0.3	0	0	0	0
Control			0	0	0	0	0	0
No. of sites:			1 + 2	2	2	1	1	3
Growth stage at spraying:		Time 1	2-5 leaf 5-10 cm	Cot-1 leaf	2-4 leaf	-	-	-
		Time 2	6-7 leaf 20-30 cm	4-8 leaf	4-8 leaf	20-40 cm	20-40 cm	4-8 leaf
		Time 3	7-10 leaf 40 cm	8-10 leaf 10-15 cm	8-14 leaf 15-30 cm	30-60 cm	60 cm	25-40 cm

Table 5

Field trials - mean percent damage to onions (4 sites) from 3,6-dichloropicolinic acid

Dose rate (g a.e./ha) 2 leaf	3-4 leaf	4-5 leaf	1 week after treatment	1 month after treatment
100	-	-	2.7	1.2
200	-	-	6.6	2.9
400	-	-	24.2	5.9
-	100	-	1.6	1.7
-	200	-	3.2	3.0
-	400	-	15.7	5.8
-	-	200	3.0	2.1
-	-	400	6.9	6.9
100 +	200	-	6.3	4.4
-	100 +	200	3.8	5.2
methazole	-	-	3.4	4.2
100 + methazole	-	-	5.9	3.2
200 + methazole	-	-	15.3	7.6
Control			0	0

As in screening trials, onions proved only moderately tolerant to 3,6-dichloropicolinic acid. However, a clear response to both dose and timing was evident, 100 g a.e./ha causing only minor effects at the 2 true leaf stage, whereas 200 g a.e./ha became safer if treatment was delayed until the 3-4 true leaf stage. Damage consisted of leaf twisting and, in more serious cases, prostration and slight chlorosis. It was most marked shortly after treatment, and considerable recovery was noted in the crop after one month.

When added to a standard dose (2.1 kg a.i./ha) of methazole, 100 g a.e./ha 3,6-dichloropicolinic acid slightly increased damage soon after spraying, but after one month this mixture was similar to methazole alone. The addition of 200 g a.e./ha caused a marked increase in damage, which was less readily outgrown.

Weed Control (see Table 6)

Single applications of 3,6-dichloropicolinic acid were only partially successful in control of *Cirsium arvense*, due to the long period of emergence in arable fields. Early applications, when the largest *C. arvense* were just beginning to produce flowering shoots, gave excellent control at first, but further emergence reduced overall control levels considerably. At later applications, the earliest emerging *C. arvense* were too large for adequate control, except with the high rate of 400 g a.e./ha. The most effective treatment proved to be a sequential application of 100 + 200 g a.e./ha (as recommended in beet crops), which killed or suppressed early-emerging *C. arvense* with a first treatment, and cleared late emergers by a second treatment some three weeks later.

Table 6

Field trials - mean percent control of composite weeds with 3,6-dichloropicolinic acid

Dose rate (g a.e./ha) Time 1	Time 2	Time 3	*Cirsium arvense*	*Tripleurospermum maritimum*	*Matricaria matricarioides*	*Senecio vulgaris*
100	-	-	51	97	-	-
200	-	-	58	99	-	-
400	-	-	68	100	-	-
-	100	-	33	86	67	99
-	200	-	74	92	100	100
-	400	-	88	96	100	100
-	-	200	45	61	100	67
-	-	400	61	89	100	93
100 +	200	-	86	-	-	-
-	100 +	200	58	-	-	-
Control			0	0		
No. of sites:			3	5	1	1
Growth stage at spraying:		Time 1	15-30 cm rosettes, 5-10 cm tall	Cot-4 leaf	-	-
		Time 2	20-40 cm tall	4-6 leaf	4-6 leaf	4-6 leaf
		Time 3	40-60 cm tall	8 leaf - 30 cm	8 leaf - 30 cm	8 leaf - 30 cm

Annual composite weeds such as *Tripleurospermum maritimum spp inodorum* were well controlled by early applications of 100 g a.e./ha, becoming somewhat more resistant as they grew larger.

DISCUSSION

At this stage in a continuing development programme, a number of potential new areas of use for 3,6-dichloropicolinic acid have been identified. In sweet corn and maize, *Cirsium arvense* is resistant to commonly used residual herbicides such as atrazine, and in the absence of competition from either other weeds or young corn plants, can rapidly become a major problem. 3,6-dichloropicolinic acid appears safe to this crop from the two leaf stage of growth, and a sequential use of 100 g a.e./ha followed by a further 200 g a.e./ha about three weeks later offers effective control of *Cirsium arvense*.

Cirsium arvense is also a problem in both brassica and onion crops, and in addition annual composite weeds such as *Tripleurospermum maritimum* or *Senecio vulgaris* are partially resistant to many herbicides used in these crops. 3,6-dichloropicolinic acid appears acceptably safe to cabbage, brussel sprouts and cauliflower under 1980 field conditions, and safe to onions treated at the appropriate growth stages. These stages appear to be 2 true leaves for 100 g a.e./ha, and 3-4 true leaves for 200 g a.e./ha. Provided that these levels of safety are confirmed by yield data, 3,6-dichloropicolinic acid offers control of *Cirsium arvense* in brassica and onion crops when applied in a sequential dose of 100 + 200 g a.e./ha. A single early 100 g a.e./ha dose also offers control of annual composite weeds. This treatment may prove safe in tank-mix with methazole in onions, and tank-mixes with other herbicides, such as aziprotryne or desmetryne, are being investigated for brassica crops.

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PROPACHLOR FORMULATIONS ON THEIR OWN, AS A TANK-MIX WITH CHLORTHAL-DIMETHYL OR WITH SEQUENTIAL APPLICATIONS OF NITROFEN AND TRIFLURALIN IN SWEDES, ONIONS AND CABBAGES

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Summary Results of six trials are reported in which the wettable powder formulation of propachlor is compared with the flowable formulation, for weed control in swede, onion and cabbage crops. Tank-mixtures of both formulations with chlorthal-dimethyl and sequential applications with nitrofen and trifluralin are also discussed. The spectrum and level of weed control obtained with the propachlor formulations is improved when the chlorthal-dimethyl is added as a tank-mixture and the sequential treatments also improve the weed control but to a lesser extent.

Crop safety is still high with the tank-mixtures of both propachlor formulations and there is no difference in the activity between the two formulations.

Résumé Rapport est fait sur les resultats de 6 assais dans lesquels la formulation de propachlore en poudre mouillable est comparee a la formulation autosuspensible, pour la destruction des mauvaises herbes en cultures de rutabagas, oicnons et divers choux.

Les melanges extemporanes des 2 formulations avec le chlorthal-dimethyl, et les applications separees avec le nitrofene et la trifluraline sont egalement discutes.

Le spectre d'activite et l'efficacite obtenues avec les formulations de propachlore augmentent lorsque le chlorthal-dimethyl est utilise en melange extemporane, et les produits appliques separement ameliorent egalement l'efficacite herbicide quoique a un niveau moindre.

La selectivite sur cultures reste elevee avec les melanges extemporanes des 2 formulations de propachlore et il n'existe aucune difference d'action entre ces 2 formulations.

INTRODUCTION

The wettable powder formulation of propachlor has been available to growers and farmers for a number of years and despite it's short-term residual activity has been used extensively, having achieved a reputation for crop safety. In recent years joint recommendations with chlorthal-dimethyl, trifluralin and chlorpropham have broadened the weed spectrum.

One disadvantage has been the inherent problems associated with using a wettable powder formulation, namely mixing, although the 'easy-fill' bag method did alleviate this problem to a certain extent.

A flowable formulation of propachlor conferred improvements to the growers and farmers in the use and handling of the herbicide. The new flowable formulation of propachlor does not appear to have altered the weed spectrum with Matricaria spp. continuing to be susceptible.

METHOD AND MATERIALS

Six field experiments, all using randomised block design with either three or four replicates, were carried out in 1979. Plot sizes were either 4 x 10m or 4 x 15m. Details of experimental sites are at Table 1.

Treatments were applied with a modified Oxford Precision Sprayer (O.P.S.) using a 2m boom with Tee-jet nozzle tipes (No.11003) except for trifluralin granular which was applied with a Fischer Airflow applicator. Sprays were applied in 500 l/ha at a pressure of 1.4 bars.

TABLE 1

Experimental Site Details

Site Number	Location	Crop	Cultivar	Soil Type	pH	O.M%
1	Boston, Lincs.	Salad Onion	Hydeal	VFSL	7.2	2.4
2	Wetherby,Yorks.	Bulb Onion	Balstora	SL	6.2	2.9
3	Pershore, Worcs.	Salad Onion	White Lisbon	ZyL	7.0	8.0
4	Cropthorne,	Cabbage	Hispi	CL	6.5	3.0
5	Elgin, Grampian.	Swede	Wilhemsburger	SL	5.4	4.5
6	Inverness,	Swede	Ruta Øtofte	SL	6.5	5.8

O.M. - Organic Matter percentage.

Application and agronomic details of the experimental sites (Table 2) include site 3 where two separate trials were conducted.

TABLE 2

Application & Agronomic Details

Site Number	Dates in 1979 Drilling/ Planting	Application	Metrological Data % RH	Temperature - °C Soil	Air	Rainfall mm Total for 7 D.A.T.
1	16.4	27.4	27	13	6	16.8
2	21.4	8.5	90	10	14	6.5
3	21.6	27.6	28	19	22	25.4
3	21.6	3.8	60	21	22	24.0
4	18.4	26.4	50	10	14	22.3
5	22.5	22.5	44	14	20	17.6
6	22.5	23.5	90	12	17	11.1

D.A.T - Days after treatment
R.H - Relative Humidity

The pre-emergence application of herbicides were made within 1 day of drilling.

Assessments of crop vigour, establishment and control of broad-leaved weeds were carried out within the eight-week residual life of propachlor.

Treatments varied according to the crop treated and included some of those listed in Table 3. All the products used were commercially available formulations.

TABLE 3

Treatment Details

Treatment Number	Herbicide		Formulation	Active Ingredient	Rate kg a.i/ha
1	propachlor		Flowable	480 g/l	4.32
2	propachlor		w.p.	65% w.w.	4.55
3	chlorthal-dimethyl		w.p.	70% w.w.	4.5
4	trifluralin		Granular	5% w.w.	1.1
5	propachlor		Flowable +		4.32 +
	chlorthal-dimethyl		w.p.		4.5
6	propachlor		w.p. +		4.55 +
	chlorthal-dimethyl		w.p.		4.5
7	propachlor)	Seq.	Flowable +		4.32 +
	trifluralin)		Granular		1.1
8	propachlor)	Seq.	Flowable +		4.32 +
	nitrofen)		e.c.	250 g/l	1.0
9	propachlor		Flowable +		4.32 +
	chloridazon/chlorbufam		e.c.	420 g/l	3.03
10	propachlor		Flowable		8.64
11	Untreated				--

Subsequent references in Results to treatment number refer to those listed in Table 3.

RESULTS

Crop phytotoxicity

Assessments were made on crop vigour using a scale of 0-10, with 10 being healthy and 0 being complete absence of crop. Crop emergence was also assessed at intervals varying from 30 to 45 days after treatment using a percentage assessment compared with untreated.

Results of both types of assessment are at Table 4.

TABLE 4

Phytotoxicity to Treated Crop

Treatment	Crop Vigour					Crop Emergence - %			
	Trial Site								
	1	2	3	5	6	1	2	5	6
1	10	10	8.8	9.6	9.3	96	100	99	100
2	10	10	9.6	7.8	9.6	97	96	90	100
3	10	10	8.7	9.6	9.5	97	100	100	100
4	-	-	-	10	9.6	-	-	100	100
5	10	10	9.1	8.5	9.5	96	100	96	100
6	10	10	8.7	9.2	9.0	99	100	98	100
7	-	-	-	8.5	8.1	-	-	78	100
8	-	-	-	7.7	9.2	-	-	94	100
9	-	-	8.8	-	-	-	-	-	-
10	9.5	10	8.9	-	-	92	100	-	-
11	10	10	10	10	10	100	100	100	100

These results show that no treatment significantly affected crop vigour on any site. Doubling the rate of propachlor flowable did not affect crop vigour or establishment. The sequence of propachlor flowable with trifluralin granules was marginal

TABLE 5
Weed Control - %

Treatment	Chenopodium album.	Poa annua	Polygonum aviculare	Polygonum convolvulus	Polygonum persicaria	Tripleurospermum maritimum	Stellaria media	Solanum nigrum	Urtica urens	Veronica hederifolia	Veronica persica
1	80	95	65	54	93	90	98	100	99	52	68
2	79	89	59	53	63	91	93	86	89	49	56
3	86	37	90	14	63	51	100	95	66	99	88
4	65	70	51	43	-	30	-	-	-	-	-
5	97	96	97	81	95	95	100	100	99	100	99
6	97	90	95	80	97	91	100	98	99	98	96
7	91	95	68	68	-	92	-	-	-	-	-
8	79	95	49	11	-	94	-	-	-	-	-
9	98	-	-	-	100	-	-	-	-	-	-
10	90	-	50	90	99	97	100	98	99	66	99
11	38	47	8.7	46	20	20	20	2	19	13	5
Sites Occurring	5	1	3	3	2	3	1	1	1	1	1

Treatment 11 refers to weed population/m^2 in the untreated plots.

on crop phytotoxicity but the crop outgrew initial symptoms.

Weed Control

Weed control was assessed on all sites by counting emerged weeds on all plots and expressing these in terms of percentage reduction compared with weed populations on the untreated plots (Table 5).

The results show that there were no biologically significant differences in the weed control produced by propachlor wettable powder or flowable formulation.

When either propachlor formulation was tank-mixed with chlorthal-dimethyl the biological results were similar and the tank mixture was also compatible physically. The tank mixtures both improved overall weed control compared with either formulation of propachlor or chlorthal-dimethyl used alone.

The double dose of propachlor flowable improved the level of control of those weeds known to be susceptible to propachlor but did not expand the weed spectrum.

The sequential use of the formulated mixture of chloridazon with chlorbufam produced a very high level of weed control.

DISCUSSION

In the three swede trials, the tank mixture of propachlor and chlorthal-dimethyl improved the weed control activity of either dose on the moderately susceptible species such as Polygonum aviculare, with an increase in control of 50% with the inclusion of chlorthal-dimethyl. Control of Chenopodium album which is classed as moderately resistant to propachlor, was improved by 25% in the tank-mixture with chlorthal-dimethyl. Control from the sequential treatments of propachlor with the trifluralin granule and nitrofen was similar to the control achieved with the chlorthal-dimethyl, although the trifluralin sequence gave slightly better control of Polygonum convolvulus and C.album than the nitrofen sequence with the propachlor flowable.

The pattern of weed control was similar on the onion trials with moderately susceptible weeds becoming susceptible with the inclusion of chloridazon plus chlorbufam treatments.

Throughout the trials series, the flowable formulation of propachlor did not impart additional weed spectrum activity when compared to the standard wettable powder formulation, and crop safety was unaltered.

A decision has now been made to replace the wettable powder formulation with the flowable formulation.

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NOTES

EXPERIMENTS WITH TANK-MIXES OF CHLORTHAL-DIMETHYL AND DIPHENAMID FOR WEED CONTROL IN RUNNER BEANS

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Summary Field experiments were conducted on a sandy loam over 3 years to evaluate soil-applied herbicides in runner beans grown as a pinched crop. Tank-mixes of chlorthal-dimethyl at 3.0-4.5 kg a.i./ha with diphenamid at 3.0-4.5 kg a.i./ha applied pre-emergence gave excellent control of annual weeds with no adverse effects on the crop. Chlorthal-dimethyl killed or suppressed several species which are resistant or only moderately susceptible to diphenamid, including *Solanum nigrum* which is a particular problem in this crop; diphenamid killed the Compositae and Cruciferae which are resistant to chlorthal-dimethyl. The merits of this proposed treatment are discussed.

INTRODUCTION

Runner beans are a relatively minor vegetable crop, with approximately 1900 ha in England and Wales of which rather less than a third are grown as a 'pinched' crop without supports (Anon., 1979). Although there is a range of herbicides which can be used to control weeds in runner beans (Anon., 1979a), there is room for improvement. One weed which has assumed increasing importance in recent years is *Solanum nigrum* which has become particularly prevalent where trifluralin has been regularly used. This species, together with other weeds resistant to trifluralin, can be controlled by following up with a post-emergence spray of bentazone (Roberts *et al*., 1974) but in practice there are often difficulties in applying post-emergence treatments in the supported crop. Moreover, further emergence of *S. nigrum* may occur after bentazone treatment. Experiments have been carried out both at the National Vegetable Research Station and by the Agricultural Development and Advisory Service (Bate, 1978; Foster, 1979) to evaluate treatments which might provide more effective weed control in the runner bean crop. In this report, the possible use of a combined pre-emergence application of diphenamid and chlorthal-dimethyl is considered.

METHOD AND MATERIALS

All the experiments were of randomised block design with three replicates, and were carried out on a sandy loam soil with approximately 2% o.m. The plot size for the experiments with runner beans was 7 m^2, containing 27 plants in three rows 46 cm apart. A base dressing of fertilizer was given, the weathered furrow was ring-rolled, and the herbicides to be incorporated were applied. The whole area then received a single pass of a rotary power harrow working to a depth of 10 cm which prepared the seedbed and incorporated the herbicides into the top 5 cm of soil. Seeds of cv. Kelvedon Marvel were sown by hand at two per station; the plants were subsequently thinned where necessary and grown as a pinched crop. The pre-emergence sprays were applied shortly after sowing in a volume of 1120 l/ha; post-emergence sprays of bentazone were applied in 450 l/ha. Surviving weeds were allowed to remain in the treated plots. Each replicate contained a single untreated plot which was not weeded and two which were kept clean by hoeing and hand-weeding.

Effects on weeds were assessed by counting survivors in a number of random quadrats on each plot, by visual scoring for weed kill on a scale of 0 (no effect) to 10 (complete kill), and by recording the fresh weight of weed vegetation at final harvest. Effects on the crop were assessed by visual scoring and by recording the weights of marketable beans picked on several occasions. The total weights are expressed as percentages of the values for the hand-weeded controls, and those which were significantly less are indicated by single (P = 0.05) or double (P = 0.01) asterisks.

To determine the persistence of activity of mixtures of chlorthal-dimethyl and diphenamid against weeds, four experiments similar to those described earlier for propachlor and chlorthal-dimethyl (Roberts _et al_., 1978) were carried out. Seedbeds were prepared, plots of 1.8 x 1.5 m were marked out and the treatments applied. These comprised diphenamid alone at 4.5 kg a.i./ha, chlorthal-dimethyl alone at 10.0 kg a.i./ha and different ratios of the two herbicides. There were two untreated control plots in each of the three replicate randomized blocks per experiment. After a period of 4-8 weeks, when the first flush of seedling emergence appeared to be complete, counts of surviving plants of each weed species were made either on the whole plot or in ten 15 x 15 cm quadrats, depending on the density. The whole area was then sprayed with paraquat and all vegetation killed. The plots were left undisturbed and when a further flush of seedling emergence had taken place the counts were repeated. In the Tables the results are expressed as percentage reductions in total weed numbers from those on the untreated control plots.

RESULTS

Experiments on runner beans

In an experiment in 1978, the main weeds were _Lamium amplexicaule_, _Veronica persica_, _Capsella bursa-pastoris_, _Urtica urens_ and _Fumaria officinalis_. The soil was moist at the time of sowing and there were 6 mm of rain in the first week, but this was followed by a dry spell. The bentazone treatments were applied when the beans had two trifoliate leaves. It was cool at the time, but high temperatures followed and bentazone caused an appreciable degree of leaf scorch which resulted in significant yield loss (Table 1).

Table 1

Weed control in runner beans, 1978

Treatment (kg a.i./ha)	Weeds: Kill (0-10)	Weeds: Reduction in wt.(%)	Crop: Injury (0-10)	Crop: Relative marketable yield
Trifluralin 0.84 inc. + bentazone 1.4 post-	9.5	96	2.3	71**
Chlorthal-dimethyl 4.5 pre- + bentazone 1.4 post-	9.0	94	2.0	77**
Chlorthal-dimethyl 2.97 pre- + methazole 0.41 pre-	7.7	69	0	96
Chlorthal-dimethyl 3.96 pre- + methazole 0.54 pre-	7.7	82	1.0	101
Trifluralin 0.48 inc. + diphenamid 3.35 inc.	8.7	89	0	99
Chlorthal-dimethyl 4.5 pre- + diphenamid 3.35 pre	9.0	93	0	99
Unweeded control (77 weeds/m^2)	-	-	-	64**
Weeded control	-	-	-	100

The control of weeds was good whether bentazone followed trifluralin or chlorthal-dimethyl. Chlorthal-dimethyl + methazole (as Delozin S), however, gave only moderate control with Fumaria officinalis, Euphorbia helioscopia and some Chenopodium album surviving. At the higher rate a few plants in each replicate plot showed marginal necrosis of the unifoliate leaves attributable to the methazole, although yield was not affected. The combinations of trifluralin + diphenamid and chlorthal-dimethyl + diphenamid both gave good weed control with no adverse effects on the crop.

Some of the treatments were again examined in 1979. After sowing, the weather was cold and wet and emergence was slow to begin. During emergence, however, the soil dried and because of capping the crop stand was irregular; for this reason yields are presented both on a per plot and a per plant basis in Table 2. The main weeds were Poa annua and Capsella bursa-pastoris, with frequent Stellaria media, Tripleurospermum maritimum ssp. inodorum, Chenopodium album and Solanum nigrum, and on the unweeded plots there was severe competition and loss of yield (Table 2).

Table 2

Weed control in runner beans, 1979

Treatment	Weeds		Crop		
	Kill	Reduction in	Injury	Relative marketable	
(kg a.i/ha)	(0-10)	wt.(%)	(0-10)	yield	
Trifluralin 0.84 inc. + bentazone 1.4 post-	9.2	91	3.3	74**[a]	84[b]
Chlorthal-dimethyl 3.96 pre- + methazole 0.54 pre	9.2	93	0.5	96	101
Trifluralin 0.48 inc. + diphenamid 3.35 inc.	8.3	82	1.2	82	79
Chlorthal-dimethyl 4.5 inc. + diphenamid 3.35 inc.	8.3	74	0.7	78*	85
Chlorthal-dimethyl 4.5 pre- + diphenamid 3.35 pre-	9.2	93	0.3	85	98
Unweeded control (220 weeds/m^2)	-	-	-	16**	13*
Weeded control	-	-	-	100	100

[a] Yield per plant; [b] yield per plot.

Bentazone effectively controlled the weeds which survived trifluralin, even though it was applied relatively late because of slow crop emergence. There was again an appreciable degree of leaf scorch, however, and probably also some weed competition before application which resulted in a significant depression of yield per plant. Chlorthal-dimethyl + methazole gave good control in this experiment, with only some Tripleurospermum maritimum ssp.inodorum, Solanum nigrum and Euphorbia helioscopia surviving, and the only effect on the crop was slight marginal leaf chlorosis on a few plants. Trifluralin + diphenamid incorporated gave fairly good weed control, but the main survivor was Solanum nigrum. This was also one of the surviving species where chlorthal-dimethyl and diphenamid were incorporated, and which resulted in significant depression of yield per plant through competition. When this combination was applied pre-emergence, weed control was good. The only surviviors were Fumaria officinalis and some plants of Solanum nigrum, which were small, distorted and non-competitive.

In 1980, particular attention was directed to the chlorthal-dimethyl/diphenamid combination applied pre-emergence and two experiments were carried out with different ratios of the herbicides. The first was sown in early May during a dry period with only 13 mm of rain during the first 3 weeks; irrigation was therefore given on three occasions. The second was sown in early June at the end of the dry spell, and after a single irrigation was subjected to prolonged cold, wet weather. In both experiments the main weeds present were Poa annua, Capsella bursa-pastoris, Veronica persica and Stellaria media, with some Lamium amplexicaule, Chenopodium album and other species.

Table 3

Weed control in runner beans, 1980

Kg a.i./ha pre-emergence Chlorthal-dimethyl		Diphenamid	Weeds Kill (%) I	II	Kill (0-10) I	II	Crop Injury (0-10) I	II	Relative marketable yield I	II
3.0	+	1.5	93	96	8.8	9.0	0	0.7	126	113
3.0	+	3.0	96	100	9.4	9.7	0	0.3	91	113
3.0	+	4.5	94	100	9.4	9.8	0	0.3	93	97
4.5	+	1.5	92	97	9.0	9.1	0	0	101	103
4.5	+	3.0	96	100	9.6	9.8	0	0.3	111	101
4.5	+	4.5	99	100	9.8	9.9	0	0	100	118
Unweeded control		(I, 223 weeds/m^2; II, 238 weeds/m^2)					-	-	43**	29**
Weeded control							-	-	100	100

Weed control with chlorthal-dimethyl + diphenamid was consistently good (Table 3). There was little difference in performance when the rate of each component was 3.0 kg a.i./ha or more, but it was less good with only 1.5 kg a.i./ha of diphenamid. With this treatment plants of Capsella bursa-pastoris, Senecio vulgaris and other species resistant to chlorthal-dimethyl tended to survive. At the higher rates, the only survivors were Fumaria officinalis together with isolated plants of C. bursa-pastoris. There was no injury to the crop which could be ascribed to the treatments, and none caused any significant reduction in marketable yield compared with that of the weeded controls. There was also no significant effect on maturity as determined by comparing the yields from the first two harvests with total yields.

Persistence of weed control

The first experiment was begun in early March, and there were 50 mm of rain during the 3 weeks after spraying. All treatments gave good control of the main weeds, Lamium purpureum, Stellaria media and Veronica persica, with the highest percentage kills where 4.0 kg a.i./ha or more of chlorthal-dimethyl was combined with 3.0 kg a.i./ha or more of diphenamid (Table 4). L. purpureum was the main species present in the second flush and was also the main survivor; its regular distribution accounts for the variation in the data. The other most frequent species, Veronica persica, Poa annua and Chenopodium album, were effectively controlled.

The second experiment was begun in a dry spell with only 7 mm of rain in the first 3 weeks. The main weeds were Lamium purpureum, Stellaria media, Veronica persica, Euphorbia helioscopia and Chenopodium album. On the plots with combined treatments, the main survivors were L. purpureum and E. helioscopia and the percentage kills were fairly low. However, many plants of L. purpureum were very stunted and the overall weed control was better than the figures (Table 4) suggest. Counts of the second flush showed that chlorthal-dimethyl still had appreciable activity, but that of diphenamid was much less. L. purpureum was again the main survivor

The third experiment received 51 mm of rain in the first 3 weeks, and the main weeds were Lamium purpureum, Poa annua, Stellaria media, Chenopodium album and Euphorbia helioscopia. Again, overall control of weeds was better than the percentage

Table 4

Effect of diphenamid (D) and chlorthal-dimethyl (C) on weed establishment

Kg a.i./ha		% kill: Applied 4 March 1980					Applied 22 April 1980				
(C)		0	2.0	4.0	6.0	10	0	2.0	4.0	6.0	10
		Counted 1 May					Counted 9 June				
(D)	0	-	-	-	-	83	-	-	-	-	74
	1.5	-	73	87	85	-	-	41	69	71	-
	3.0	-	86	94	93	-	-	53	71	79	-
	4.5	83	87	96	95	-	37	58	63	68	-
Control density				$135/m^2$					$95/m^2$		
(D)	0	-	-	-	-	80	-	-	-	-	95
	1.5	-	18	80	-	-	-	38	93	95	-
	3.0	-	49	100	51	-	-	53	95	100	-
	4.5	78	64	87	82	-	7	61	84	100	-
Control density				$43/m^2$					$37/m^2$		

kills in Table 5 suggest since many of the remaining plants of <u>L. purpureum</u> were severely stunted although still alive at the time of counting. This was also true for <u>Solanum nigrum</u>, of which plants were also present. Chlorthal-dimethyl gave a high degree of kill of the second flush of weeds, but diphenamid had little effect on the numbers of <u>Lamium purpureum</u> and <u>L. amplexicaule</u> present.

Table 5

Effect of diphenamid (D) and chlorthal-dimethyl (C) on weed establishment

Kg a.i./ha		% kill: Applied 23 May 1980					Applied 5 June 1980				
(C)		0	2.0	4.0	6.0	10	0	2.0	4.0	6.0	10
		Counted 26 June					Counted 8 July				
(D)	0	-	-	-	-	70	-	-	-	-	86
	1.5	-	83	69	92	-	-	94	95	96	-
	3.0	-	60	78	83	-	-	97	98	98	-
	4.5	77	75	80	87	-	95	99	98	100	-
Control density				$191/m^2$					$312/m^2$		
		Counted 13 August					Counted 13 August				
(D)	0	-	-	-	-	96	-	-	-	-	50
	1.5	-	92	91	98	-	-	14	5	50	-
	3.0	-	83	95	100	-	-	50	55	68	-
	4.5	47	100	98	96	-	83	73	77	69	-
Control density				$51/m^2$					$21/m^2$		

The final experiment also received heavy rainfall during the first few weeks and the main weeds were <u>Capsella bursa-pastoris</u>, <u>Stellaria media</u>, <u>Matricaria</u> spp. and

Poa annua. The surviving species with chlorthal-dimethyl alone were C. bursa-pastoris, Matricaria spp. and Senecio vulgaris, while with diphenamid alone the main survivors were Lamium amplexicaule and Solanum nigrum. The combined treatments all gave high percentage kills (Table 5), and those plants of L. amplexicaule and S. nigrum which remained were generally small and non-competitive. The main species in the second flush was Senecio vulgaris, which was killed only where the higher rates of diphenamid had been applied.

DISCUSSION

Diphenamid and chlorthal-dimethyl are to a large extent complementary in their activity against the common annual weeds of vegetable crops. Solanum nigrum, which is resistant to diphenamid, is controlled by chlorthal-dimethyl which also supplements the rather limited activity of diphenamid against Polygonum spp. and Chenopodium album. Diphenamid controls Senecio vulgaris, Capsella bursa-pastoris, Thlaspi arvense and Matricaria and Tripleurospermum spp. which are resistant to chlorthal-dimethyl and supplements its limited activity against Poa annua. Other common species, such as Stellaria media and Veronica persica, are susceptible to both herbicides. Fumaria officinalis is resistant to both, but is unlikely to be a serious problem in the runner bean crop.

Diphenamid at rates of up to 4.5 kg a.i./ha has been commercially recommended as a pre-emergence treatment for runner beans in the UK for some years. Chlorthal-dimethyl on the evidence of the present experiments also appears to present no risk of crop injury, and there was no adverse effect when each of the two herbicides was applied at 4.5 kg a.i./ha (Table 3). Earlier tests with chlorthal-dimethyl showed no crop injury with rates twice as high as this. Further work would be needed to establish the optimum ratio for providing effective weed control. Even on this relatively light soil it appears that at least 3.0 kg a.i./ha of each herbicide would be needed and in other situations 4.5 kg a.i./ha would probably be required. Activity would not be expected on highly organic soils, and in pot tests with a clay soil containing 7.6% o.m. Damanakis & Paspatis (1979) found that chlorthal-dimethyl did not affect Solanum nigrum at rates up to 13.5 kg a.i./ha. However, in these tests the herbicide was incorporated into the top 15 mm of soil, and assessments were made after 21 days. Both these may have contributed to the observed lack of effect; we have consistently found that with S. nigrum in particular emergence is often normal and the effects of chlorthal-dimethyl develop slowly before ultimate cessation of growth.

Diphenamid is considered to be relatively persistent in soil (Weed Science Society of America, 1979) while chlorthal-dimethyl was found to have a half-life of rather more than 3 months when applied in May (Roberts et al., 1978). The results in Tables 4 and 5 indicate that combined treatments are likely to remain effective for an adequate period. We suggest, therefore, that a combined pre-emergence application of chlorthal-dimethyl and diphenamid merits further evaluation for weed control in runner beans.

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NOTES

WEED CONTROL IN OUTDOOR BLOCK RAISED TRANSPLANTED LETTUCE - PROGRESS REPORT OF AGRICULTURAL DEVELOPMENT AND ADVISORY SERVICE EXPERIMENTS

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Summary. Trials at three centres indicate that propachlor and possibly butam offer scope for the control of composite weeds in outdoor transplanted lettuce. Butam with adequate protection to the transplant from charcoal dipping gave the least check to the plants in both yield and maturity date. Propachlor without the use of charcoal dipping delayed maturity 5-7 days, without any serious reduction in yield. The effect of propachlor was more marked on small transplants. Overall sulfallate was the best herbicides, but it is no longer commercially available.

INTRODUCTION

The doses of herbicides available commercially for use in this crop do not effectively control composite weeds, notably Senecio vulgaris and Matricaria spp. As successive crops are often taken from the same land, build up of resistant weeds quickly occurs. The Agricultural Development and Advisory Service have been engaged in a programme of work to look for suitable safe herbicides. Some of this work was reported by Jones and Suckling (1978). This indicated that sulfallate applied pre-planting to the hand planted crop at up to three times the dose at present in the recommended dose of the commercial product was very promising.

The soil disturbance at planting by hand and more so by a share and coulter type machine reduced the effectiveness of the herbicide applied pre-planting. Therefore a herbicide which is safe to apply post-planting is desirable. It was known that propachlor has been used commercialy in this manner (Personal Communication), and had also been tried at Stockbridge House Experimental Horticulture Station (Hargreaves, 1974). It was also observed in a herbicide screening trial at the National Vegetable Research Station (Roberts, 1977), that butam applied post-crop emergence to a drilled lettuce crop, appeared to have no phytotoxic effect.

It was also thought that the use of activated charcoal, as a root dip, might protect the crop from the effect of soil acting herbicides.

These leads have been followed up in the experiments described below.

Suckling in the Thames Valley continued his assessment of sulfallate, and also tried butam and propachlor, both before and after planting by hand and also before planting with the Tospo studded roller.

Birkenshaw at Luddington Experimental Horticulture Station has evaluated propachlor applied post-planting by hand whilst Antill at Efford Experimental Horticulture Station has commenced the evaluation of charcoal root protectants.

METHODS AND MATERIALS

At all sites except Luddington, lettuce plants were raised in standard 4 x 4 cm peat blocks, planted out at approximately the 4 leaf stage. At Luddington, size of transplants was included as one of the experimental treatments. This was achieved by sowing three weeks earlier for the large transplants. At all centres standard commercially available butterhead varieties were used.

The herbicide treatments used were sulfallate as the 48% e.c. formulation at 4.06 and 6.09 kg/ha (2 and 3 times the commercially recommended dose); propachlor as a 65% w.p. at doses ranging from 2.9-4.4 kg/ha; butam as 72% e.c. formulation at doses of 2.16-8.64 kg/ha; and asulam as a 40% a.c. at 0.56-1.12 kg/ha.

In the first of three trials in the Thames Valley, the herbicides were applied to the soil surface before planting by hand, over the lettuce after planting by hand in the second, and before machine planting with a Tospo studded roller planter in the third.

In the trial at Luddington all the treatments were applied after hand planting, whilst at Efford the pre-planting herbicides were applied, then the planting hole was drenched with a slurry of activated charcoal. For the post-planting herbicide treatment the lettuce blocks were dipped in the slurry before planting. All the herbicides were applied in 200 litre/ha using an Oxford Precision Sprayer.

All the experiments were randomised blocks with 3 or 4 replicates. Plot size varied with centre but were generally of 10 m^2 or greater, the number of recorded plants per plot or sub-plot being not less than 24. At Luddington plots were divided into 3 sub-plots for harvesting, which occurred at approximately 3 day intervals. At Efford the plots were halved, the first harvest being made when the majority of the trial was considered mature, whilst for the second harvest, treatments were harvested individually when they were considered mature. This varied from 11 July for the untreated control to 24 July for plots which had received propachlor pre-planting.

Weed counts, where appropriate were made either from the whole plot of $10m^2$ where weed numbers were low, or from 8 to 10 x $1/10m^2$ quadrats per plot in experiments where weed numbers were high.

RESULTS

<u>Effect on yields</u>

In the Thames Valley trials (table 1 to 3) applying sulfallate or asulam before planting by hand, trial 1, was safe but butam reduced yield at all doses, significantly at the three higher doses. Applying herbicide after planting by hand, trial 2, produced some check to the plants, and consistently reduced yield, significantly so with butam and propachlor.

Applying the herbicides before planting with a Tospo studded planter, trial 3, severely checked all treatments, even the sulfallate treatment which had proved safe in the earlier trials.

In the Luddington trial (tables 4 and 5), at the first harvest all the herbicide treated plots yielded less than their respective untreated controls, the difference reaching a significance in the case of the small transplants. The percentage of marketable heads followed the same pattern.

By the second harvest, though yields overall had increased the herbicide treated plots still yielded less than their respective untreated controls, the difference again reaching significance in the case of the small transplants. By the third harvest, the difference in yield had been maintained, but the percentage of marketable heads had risen and only on the small transplants with the highest dose of propachlor was it significantly lower than the control,

At Efford, (tables 6 to 8), from the first harvest, when all plots were cut on the same date, there were significant effects of both herbicides and application time, the highest yielding treated plots being similar to the untreated. Butam produced greater yields than propachlor, whilst pre-emergence applications produced lower yields than post-emergence application. There was no significant effect of charcoal dipping on yield, and only when comparing the effect of charcoal dipping on propachlor applied pre-planting was there a significant increase in mean head weight. Even so there was a fairly consistent increase in yield and mean head weight from the use of charcoal.

From the second harvest there were no significant effect of herbicide, time of application or charcoal dipping on yield or mean head weight. The relatively large differences in mean head weight between any treatment and the untreated control is due to the date of harvest, the control being harvested 6 days before the first herbicide treatment. As the difference in harvest dates made little if any difference to the marketable numbers, and no difference to head counts of herbicide damage, botrytis and others (mainly virus) these have been meaned in table 8. This shows clearly that charcoal reduces the susceptibility to herbicide damage.

Observations before harvesting showed that where herbicide damage occurred it was more severe from butam than from propachlor. This is very apparent on two of the four replicates of butam pre-planting without charcoal protection. Propachlor delayed maturity more than butam, whilst the use of charcoal reduced the delay in maturity, table 8.

Effect on weed control

Only in the Thames Valley trials, where it was considered that a high number of composite weeds were present, were weed counts made (tables 1 to 3). In the first trial both doses of sulfallate, the three higher doses of butam and the lower dose of asulam gave a significant reduction on S. vulgaris. All treatments reduced the number of Matricaria spp., the difference did not reach significance.

In the second trial, where the herbicide was applied after planting, sulfallate, butam and propachlor all gave good control of both weeds, the control being highly significant in all cases except for the control of S. vulgaris with butam, against which it is known to be less active.

Again in the third trial, sulfallate and propachlor at both doses gave highly significant control of both weeds.

DISCUSSION

To interpret the results correctly the mode of entry into the plants must be known. From observation in these and earlier trials, and also commercial grower usage, it would seem that sulfallate is taken in mainly via the roots with some leaf uptake. Propachlor behaves similarly, whilst butam appears to be entirely taken up by the roots, and is more severe in its action than either sulfallate or propachlor. This helps explain the different degree of damage produced in the three trials report from the Thames Valley. In the first, the herbicide treated soil is largely moved aside in the act of planting, making sulfallate comparatively safe, but not so the more active and mobile butam. In commercial planting by hand the lettuce blocks are never fully covered by soil, thus there are exposed roots present to take up the herbicide applied after planting (trial 2). Butam and propachlor are damaging under these circumstances. Yet in the trials at Luddington and Efford, where commercial pressures of work rate cannot apply, and deeper more careful planting took place, crop reduction was much less and never reached the level of statistical differences of the second Thames Valley trial.

Today much, if not most, of the lettuce planted mechanically is put in with a studded roller type planter of which the most common is the Tospo. This consists of a large front drum or roller which carry square studs to match the size of the peat block in which the lettuce plants are raised. This is rolled over the softly prepared beds, making indentations in which the lettuce are placed on a herbicide layer, and severe damage from root absorbed herbicides can occur. This is the situation which pertained in the third Thames Valley trial. Also with this method of planting much of the block is exposed, making it very vulnerable to herbicides applied after planting.

At this stage it became known that sulfallate was being withdrawn from the market, therefore work continued at Luddington with propachlor, to see if lettuce, properly planted, covering the block with soil would be safe to propachlor applied after planting, and if so, to which dose. Also to assess if the size of transplant had any effect on crop tolerance.

At first sight the Luddington trial would indicate a reduction in yield. However. 350 gms is a large marketable lettuce. The conversion factor for tonnes/ha to grammes per plant is approximately x 10. However, this was under ideal conditions of fertility, irrigation and weed control. If propachlor were to check growth in a crop which is already under stress from another source results may be different. Therefore it can be seen that the main effect of the propachlor has been to delay maturity by 4 or 5 days, for by the second or third harvest all the herbicide treated large transplants and most of the small transplants had reached a good marketable size. In fact the very heavy untreated controls were over mature.

The Efford trial was designed to see if it was possible to use activated charcoal to neutralise the herbicide already applied, (charcoal slurry in the hole pre-planting) or protect the lettuce blocks from herbicides to be applied after planting, (charcoal dipping the blocks before planting). The main features of this trial, to be observed in the field were a) delaying maturity from propachlor, b) the relative safety of propachlor, in that where damage in the form of stunting took place, it was not severe, c) the very damaging nature of butam where damage did occur, and d) the reduced delay in maturity from using charcoal protectants.

It would appear that with early crops where it is important to delay maturity as little as possible, butam may be preferable to propachlor, but only if good planting and the use of charcoal can be practiced. However, butam does not give so good control of <u>S. vulgaris</u> as does propachlor.

Where there is any doubt about the efficiency of planting, propachlor is undoubtedly safer than butam. It is unfortunate that sulfallate has been withdrawn as this gave good weed control and relatively good crop safety.

The high degree of weed control in the second and third Thames Valley trials clearly indicates the desirability of applying the herbicide after soil disturbance has finished. With the current methods of planting, the safe use of herbicides post-planting are likely only to be practicable if some form of protection is given to the block at planting with a share and coulter type planter. This is most likely to be achieve by directing a jet of charcoal slurry onto the shoulder of the lettuce block as it is going through the planter, whilst with a studded roller planter where the herbicide is already in the soil depression before planting directing the jet into the hole bottom.

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Table 1

Thames Valley trial - herbicide applied before planting by hand

Treatment: Herbicide	Treatment: Dose/ha	Yield tonnes/ha	Weed Counts number per 10 m^2: Senecio vulgaris	Weed Counts number per 10 m^2: Matricaria spp.
sulfallate	4.06	17.37	13.33* (1)	3.00
sulfallate	6.09	15.10	9.33* (1)	1.67
butam	2.16	14.83	34.00	1.00
butam	4.32	12.15** (1)	15.33	5.67
butam	6.48	11.29** (1)	10.67* (1)	3.73
butam	8.64	10.46*** (1)	13.67* (1)	0.33
asulam	0.56	17.64	13.33* (1)	5.67
asulam	1.12	16.66	22.67	1.33
untreated control (mean of 2 rep.)		15.88	28.00	6.33
		SED (1) 1.262	SED (1) 6.699	SED (1) 3.385
d.f. 21		SED (2) 1.458	SED (2) 7.735	SED (2) 3.909

SED (1) - for difference between herbicide treatment and control
SED (2) - for difference within herbicide treatment

Table 2

Thames Valley trial - herbicide applied after planting by hand

Treatment: Herbicide	Treatment: Dose/ha	Yield tonnes/ha	Weed Counts number per 10 m^2: Senecio vulgaris	Weed Counts number per 10 m^2: Matricaria spp.
sulfallate	4.06	16.10	0** (1)	1.0*** (1)
sulfallate	6.09	16.80	1.00** (1)	1.0*** (1)
butam	2.16	8.05***(1)	3.00	0*** (1)
butam	4.32	2.54***(1)	2.00* (1)	0*** (1)
propachlor	3.00	5.79***(1)	0** (1)	0*** (1)
propachlor	4.5	7.77***(1)	0** (1)	0*** (1)
untreated control (mean of 2 rep)		17.51	6.67	17.33
d.f 17		SED (1) 1.896 SED (2) 2.190	SED (1) 1.793 SED (2) 2.071	SED (1)4.005 SED (2)4.624

SED (1) - for difference between herbicide treatment and control
SED (2) - for difference within herbicide treatments

Table 3

Thames Valley trial - herbicide applied before machine planting with Tospo planter

Treatment: Herbicide	Treatment: Dose/ha	Yield tonnes/ha	Weed Counts number per 10 m^2: Senecio vulgaris	Weed Counts number per 10 m^2: Matricaria spp.
sulfallate	4.06	14.40*	190***	
sulfallate	6.09	14.40*	100***	
propachlor	3.00	2.97***	50***	
propachlor	4.50	0***	20***	
untreated control		16.52	440	
d.f. 10		SED 0.946	SED 24.129	

Table 4

Luddington trial 1980 - total marketable yield tonne/ha

Plant size	propachlor dose kg/ha: 0		2.9	3.6	4.4
First harvest					
small	35.87		27.94*	26.87*	21.63***
large	37.03		35.39	33.66	30.73
		SED 3.171	d.f. 14		
Second harvest					
small	46.01		33.6*	34.2*	32.1
large	50.00		42.8	47.8	42.5
		SED 4.74	d.f. 14		
Third harvest					
small	58.94		49.97*	50.59*	45.90**
large	63.46		56.99	55.64	54.67*
		SED 3.676	d.f. 14		

Table 5

Luddington trial 1980 - % marketable number

Plant size	propachlor dose kg/ha 0	2.9	3.6	4.4
First harvest				
small	90.0	78.4*	69.7***	66.2***
large	86.2	80.7	85.9	76.7*
	SED 4.36	d.f. 14		
Second harvest				
small	90.0	77.5**	74.1**	75.9**
large	86.2	82.1	86.2	78.2
	SED 7.11	d.f. 14		
Third harvest				
small	90.0	90.0	86.07	79.32*
large	86.15	90.0	90.0	82.31
	SED 3.996	d.f. 14		

Trial 6

Efford trial 1980

Yield data comparison, timing versus root protection from propachlor and butam

Treatment	Marketable Yield kg/ha 1st harvest	2nd harvest	Mean Head Weight (gms) 1st harvest	2nd harvest
propachlor pre-planting	23.02**	28.96	250.0**	345.4
propachlor pre-planting + charcoal	27.66	33.20	319.5	369.7
butam pre-planting	24.52**	28.01	279.3*	343.3
butam pre-planting + charcoal	28.21	30.74	294.7	330.2
propachlor post-planting	27.94	30.94	296.0	374.6
propachlor post-planting + charcoal	26.16*	33.13	306.1	370.0
butam post-planting	31.35	34.15	322.9	377.6
butam post-planting + charcoal	34.56	30.33	344.6	347.8
untreated control	33.67	33.06	393.1	302.1
d.f. 24	SED 2.947	SED 2.626	SED 28.172	SED 26.920

Table 7

Efford - % heads in various categories (mean of both harvests)

Treatment	Marketable	Herbicide damage	Botrytis	Others
propachlor pre-planting	81.56	6.56	10.88	1.50
propachlor pre-planting + charcoal	82.25	9.06	6.25	1.56
butam pre-planting	78.44	18.12	3.13	0.31
butam pre-planting + charcoal	86.25	8.12	5.62	0.00
propachlor post-planting	82.81	8.75	8.12	0.31
propachlor post-planting + charcoal	80.31	8.12	11.56	0.00
butam post-planting	85.31	9.69	4.69	0.31
butam post-planting + charcoal	85.94	8.13	5.58	0.31
untreated control	93.75	2.19	4.06	0.00

Table 8

Efford - mean harvest date (2nd harvest)

Treatment	With charcoal protection	No charcoal protection
propachlor pre-planting	18 July	24 July
butam pre-planting	17 July	22 July
propachlor post-planting	18 July	23 July
butam post-planting	17 July	22 July
untreated control	-	11 July

PRELIMINARY STUDIES ON THE MODE OF ACTION OF GLYPHOSATE IN FIELD HORSETAIL (*EQUISETUM ARVENSE L.*)

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Summary Field application of 2.5 and 3.5 kg a.e./ha glyphosate to the foliage of field horsetail (Equisetum arvense L.) failed to significantly reduce rhizome dry weight during the year of application and one year later. Rhizome dry weight of E. arvense was reduced most when 2.5 kg a.e./ha glyphosate was applied on 5 August 1977 (1977 assessment) and 24 June, 1977 (1978 assessment); the reductions were not statistically significant. Conventional spray volumes of 400 l/ha proved to be as effective (1977 assessment) or more effective (1978 assessment) than CDA volumes of 20 l/ha using glyphosate at 2.5 and 3.5 kg a.e./ha.

Autoradiography and quantitative radioassay studies using ^{14}C-labelled glyphosate indicated that although the uptake of ^{14}C-glyphosate into the treated shoots was good, translocation to the untreated shoot was limited and mainly acropetal. Translocation of ^{14}C-glyphosate from the treated to the untreated shoots was greatest as measured on the 6 August, 168 h treatment. Metabolism studies using ^{14}C-glyphosate showed that small quantities of intact glyphosate and its metabolite aminomethylphosphonic acid, were present after a 21 day treatment period. The extent by which glyphosate may be metabolised by E. arvense will require further study.

INTRODUCTION

Field horsetail (Equisetum arvense L.)was confirmed as a widespread weed problem in horticultural establishments in west and central Scotland by a weed survey carried out in 1978 by the Botany Department, the West of Scotland Agricultural College.

Infestations of E. arvense are common in outdoor vegetable crops, strawberry beds, bush and cane fruits, nursery stocks and also in indoor glasshouse crops. It is uncertain how much a severe infestation of E. arvense can, by competition, reduce the yield of vegetable and fruit crops. The smothering effect of the rapid early season growth of field horsetail later causes harvesting problems, especially when low-growing vegetable or fruits are to be picked by the public. Beds of strawberries may be completely abandoned due to the E. arvense growth.

The effectiveness of glyphosate as a herbicide, used to control E. arvense is unpredictable. E. arvense is variously reported to be more resistant than most perennial weeds to glyphosate (Davidson, 1972; Stryckers and Himme, 1973; Williams, 1974) or alternatively, susceptible to glyphosate (Bruge and Jean, 1977). It was decided, therefore, to investigate the movement of glyphosate within shoots and rhizomes following treatment with ^{14}C-labelled glyphosate. This should assist in defining more clearly the correct time of application of this foliage-applied translocated herbicide.

The studies were initiated in 1977, the following points being investigated:

(1) a field trial to determine the optimum time of application in relation to the susceptibility of the underground system;

(2) a field trial to examine the effect of spray application technique in relation to the susceptibility of the underground system;

(3) the uptake and translocation characteristics using ^{14}C-labelled glyphosate applied to pot-grown E. arvense;

(4) the metabolism of ^{14}C-labelled glyphosate in E. arvense.

METHOD AND MATERIALS

Field trials

Field trials using glyphosate were laid down in 1977 at Dunure, Ayrshire and Rosebank, Lanarkshire. At Dunure, glyphosate was applied using a knapsack sprayer at 2.5 kg a.e./ha on five dates in 1977 (3 June, 24 June, 15 July, 5 August, 26 August) at a volume rate of 400 l/ha. The plots were 5 x 2 m in size, with a 1 m discard between them, and the treatments were randomized with three replicates per treatment.

Ten weeks after each treatment, the shoot height and density were assessed using two 0.5 x 0.5 m random quadrats per treatment. Rhizome dry weight was also measured at this time for each treated and untreated plot using material from two 20 cm^3 random soil cores. Herbicidal activity was measured, using the same parameters, one year after treatment.

Glyphosate was applied at Rosebank at 2.5 and 3.5 kg a.e./ha at a volume rate of 400 l/ha using a knapsack sprayer and at 20 l/ha using a Micron Herbi, CDA sprayer on 31 August, 1977. The plots were 1.2 x 10 m in size, with a 1 m discard between them, and the treatments were randomized with four replicates per treatment. Ten weeks after treatment, rhizome dry weight was measured for each treated and untreated plot using two 20 cm^3 random soil cores. Herbicidal activity was measured using two 20 cm^3 random soil cores one year after treatment. The data was subjected to analysis of variance.

Laboratory studies

Culture of plants

E. arvense rhizomes from a single location were removed during 1977 and cut into two-node segments of approximately 5 cm. The segments were planted to a depth of 1 cm in 10 cm diameter pots containing John Innes No. 1 compost; after about 6 months in the glasshouse the resulting plants were transplanted into 20 cm diameter pots containing field soil and grown on outside.

Preparation of ^{14}C-labelled herbicide

(a) *Autoradiography and quantitative radioassay.* ^{14}C-methyl labelled glyphosate (1.95 mCi/mM) was gifted by Monsanto Agricultural Products Co., St. Louis, Missouri, USA. The stock solution was prepared by dissolving 2.20 mg ^{14}C-glyphosate (parent acid form) in 4.9 ml of unlabelled glyphosate, . The parent acid form of glyphosate was converted to the soluble form by adding iso-propyl-amine in a 1 : 1 molecular ratio. The stock solution contained 5μ Ci/ml and 360.4 mg/ml of glyphosate.

(b) *Metabolism studies*. ^{14}C-methyl labelled glyphosate (2.01 mCi/mM) gifted from Monsanto Agricultural Products Co., was prepared by dissolving 2.28 mg ^{14}C-glyphosate (parent acid form) in 0.79 ml of glyphosate (MON 0139, without surfactant) and made up to a final volume of 2.7 ml with 1.91 ml of distilled water. The stock solution contained 12.5 µCi/ml and 142.1 mg/ml of glyphosate.

Uptake and translocation of ^{14}C-glyphosate.

(a) *Autoradiographic studies*. Shoot systems of two year-old pot-grown E. arvense were each treated with 14 x 5 µl of ^{14}C-glyphosate (0.35 µCi, 25.22 mg glyphosate/ shoot) by a Hamilton microsyringe pipette to the mid-region of each shoot of two adjacent whorls, mid-way up the stem. Duplicate shoots were treated for 24 h and 168 h on 4 June, 25 June, 16 July and 6 August, 1979.

The treated plants were placed in a Sherer growth cabinet maintained at a day temperature of $21^0C \pm 1^0C$, a night temperature of $18^0C \pm 1^0C$ and 70% relative humidity ± 10%, with a 16 h photoperiod produced by a bank of eight 20W fluorescent tube lamps (780 J m^{-2} min^{-1} at shoot level).

After 24 h and 168h duplicate shoots were harvested from the pots together with approximately 10 cm of rhizome and tubers. Thick rhizomes and tubers were washed clean from soil and were split longitudinally before freeze drying. Each shoot was washed with 20 ml of distilled water to remove the surface residue of ^{14}C-glyphosate. The shoot and rhizome systems were frozen between sheets of perforated zinc and freeze dried at a vacuum of 10^{-2} torr for 24 h. Autoradiographs were then prepared according to the method of Crafts and Yamaguchi (1964).

(b) *Quantitative radioassay*. Shoot systems of two year-old pot-grown E. arvense were treated in an identical manner to those for the autoradiography experiments. After the treatment period of 24 h or 168 h, the surface residue was removed by washing each shoot with 20 ml distilled water. The radio-activity in the surface residue from each shoot was assayed using triplicate 4 ml samples and liquid scintillation spectrometry. Rhizomes and tubers were washed to remove any adhering soil.

After freeze drying, the shoot and rhizome system was separated into (1) treated shoots, (2) untreated shoots and (3) rhizomes and tubers. Each region was finely milled and homogenised in 10 ml of ice cold distilled water using a pestle and mortar. Each homogenate was centrifuged at 15,000 x g for 20 minutes at 2^0C and duplicate 4 ml subsamples of the supernatant removed for assay by liquid scintillation spectrometry. The pellet remaining from each sample was combusted using a Harvey Biological Oxidiser and the ^{14}C-activity of the total homogenate and the pellet combined.

Metabolism studies.

Shoot systems of two year-old pot-grown E. arvense were each sprayed with approximately 2 ml of a cationic surfactant solution containing 1% v/v Ethomeen C25 (HLB 19.3) in distilled water prior to treatment with ^{14}C-glyphosate.

Each shoot was treated immediately after the surfactant with 14 x 2 µl of ^{14}C-glyphosate using a Hamilton microsyringe pipette (0.35 µCi, 4 mg glyphosate/ shoot). Three shoots with a mean height of 21 cm were treated. The treated plant was maintained for a period of 21 days in the growth cabinet under the conditions previously described.

Each shoot was removed with approximately 10 cm of the adjoining rhizome and tuber system. Soil was washed from the rhizomes and tubers. To remove any surface residue of ^{14}C-glyphosate each shoot was washed with 50 ml of distilled water. The shoot and rhizome systems were immediately frozen, freeze dried and finely milled. The milled shoot and rhizome tissue from each plant was combined and extracted in

100 ml of distilled water for two hours in a flask maintained on an orbital shaker at 5^{0}C. After filtration through Whatman's No. 1 filter paper the plant tissue was re-suspended in a further 100 ml of distilled water and extracted as before for two hours. After filtration both homogenates were combined, freeze dried and finally redissolved in 2 ml of distilled water prior to separation by thin layer chromatography.

In this preliminary investigation, two chromatographic solvent systems were used:

A. 4 µl aliquots were chromatographed on 0.1 mm thick microcrystalline cellulose plates using a solvent system described by Sprankle, Sandberg, Meggitt and Penner (1978) consisting of ethanol 55 : water 35 : 15N NH_4OH 2.5 : TCA 3.5 g : 17 N acetic acid 2.0. The plates were developed to a distance of 17-18 cm at a temperature of 20-22^{0}C.

B. 4 µl aliquots were chromatographed on 0.25 mm thick Whatman's CC41 cellulose using a solvent system described by Ragab (1978) consisting of methanol 180 : water 60 : 0.5 M NaCl 0.3. The plates were developed to a distance of 10 cm at a temperature of 20-22^{0}C.

After drying overnight, these thin-layer chromatograms were sprayed with 0.5% ninhydrin reagent in butanol and heated at 95^{0}C for 5 minutes until the characteristic pink/violet spots developed. Reference standard solutions of glyphosate, aminomethylphosphonic acid and glycine each contained 1 mg/ml and were applied to the thin layer chromatograms in 20 µl aliquots. The R_f values for the spots were determined relative to the solvent front from the starting base of the spots. The developed chromatograms were then autoradiographed on Kodirex X-ray plates to check for radio-activity in the fractions of the extract. The data presented are the means of two experiments with two replications per experiment.

RESULTS

Field trials

The effect on plant height, density and rhizome dry weight of 2.5 kg a.e./ha glyphosate applied in 1977 at the Dunure site was assessed in 1977 and 1978 (Table 1)

There were no significant differences apparent in assessments during 1977 and 1978. Maximum reductions in plant height, density and rhizome dry weight were obtained in 1977 from glyphosate treatment on August 5. In the 1978 assessments a glyphosate treatment on June 24, 1977 appeared to have given the best long term reduction in plant height, density and rhizome dry weight.

The effect on rhizome dry weight of 2.5 and 3.5 kg a.e./ha glyphosate applied on 31 August, 1977 at the Rosebank site by conventional spray volume (400 l/ha) and CDA (20 l/ha) was assessed in 1977 and 1978 (Table 2).

There were no significant differences in assessments during 1977 or 1978. The only treatment which appeared to reduce rhizome dry weights was 3.5 kg a.e./ha glyphosate applied by the conventional spray volume of 400 l/ha.

Uptake and translocation of ^{14}C-glyphosate

(a) *Autoradiography studies.* Differences in the distribution of ^{14}C following treatment with ^{14}C-glyphosate were apparent between 24 h and 168 h treatment periods. After 24 h, only trace quantities of ^{14}C had moved acropetally from the treated to the untreated aerial shoots. By contrast, after 168 h the ^{14}C had clearly moved from the treated shoots acropetally to accumulate in the tips of untreated shoots. Basipetal movements of ^{14}C was noted only in the stems of shoots treated on 25 June and 6 August for 168 h. No ^{14}C activity was apparent in the rhizomes or tubers.

Table 1. The effect of glyphosate on plant height, density and rhizome dry weight (mean of 6 samples values).

Assessment dates: 1977: 10 weeks after treatment

1978: 1 year after treatment

Site: Dunure	Assessment (% of control)					
Date of spraying	Height		Density		Rhizome dry weight	
1977	1977	1978	1977	1978	1977	1978
June 3	166.8	75.4	192.5	72.8	139.9	114.6
June 24	131.6	62.8	115.3	66.8	69.8	76.2
July 15	102.0	95.0	109.8	108.1	146.0	137.1
August 5	69.2	73.9	79.7	72.9	55.0	119.8
August 26	200.5	94.6	135.2	97.3	102.0	119.5
SED	±30.8	±15.8	±37.3	±16.5	±41.2	±25.7
Mean	134.0	80.3	126.5	83.5	102.5	113.4

Table 2. The effect of glyphosate on rhizome dry weight (g), mean of 8, 20 cm^3 soil cores.

Site: Rosebank	Rhizome dry weight (g)	
Glyphosate treatment	1977 assessment 10 weeks after treatment	1978 assessment One year after treatment
2.5 kg a.e./ha applied at 400 l/ha	1.95	1.77
3.5 kg a.e./ha applied at 400 l/ha	1.45	1.17
2.5 kg a.e./ha applied at 20 l/ha	1.85	2.19
3.5 kg a.e./ha applied at 20 l/ha	1.80	1.74
Control (0)	1.69	1.84
SED	±0.48	±0.53
Mean	1.75	1.74

(b) *Quantitative radioassay.* The time-course of the recovery of ^{14}C from the various parts of the ^{14}C-glyphosate treated plants is presented in Table 3.

Table 3. Recovery of ^{14}C from E. arvense treated with ^{14}C-glyphosate.

		% of total ^{14}C recovered				
Treatment date	Period (h)	Surface residue	Treated shoots	Untreated shoots	Rhizomes	Recovery %
4 June	24	95.2	4.3	0.44	0.06	81.9
	168	75.7	21.5	2.63	0.13	
25 June	24	96.3	3.6	0.06	0.00	100.0
	168	55.7	44.2	0.12	0.02	
16 July	24	98.1	1.9	0.04	0.01	98.5
	168	87.7	12.1	0.15	0.01	
6 August	24	96.8	2.9	0.27	0.00	93.8
	168	73.6	22.1	4.24	0.08	
SED	±	±7.07	±6.57	±1.75	±0.03	±4.1
MEAN	24h	96.6	3.2	0.2	0.02	93.5
	168h	73.2	25.0	1.78	0.06	
SED		±3.53	±3.29	±0.87	±0.01	

The uptake of ^{14}C-glyphosate as measured by the ^{14}C activity within the surface residue and treated shoots increased significantly between the 24 and 168 h periods, for all treatment dates. The movement of ^{14}C-glyphosate into the untreated shoots did increase at all dates between the 24 and 168 h periods; however, this was not significant at the 5% level. Only the 4 June, 168 h treatment showed a significant increase in rhizome accumulation of ^{14}C during the 168 h period. The 168 h treatment on 25 June absorbed a significantly greater amount of ^{14}C-glyphosate into the treated shoots than at any other date. This high absorption did not promote further movement of ^{14}C-glyphosate since the untreated shoots contained only 0.12% of the total ^{14}C recovered.

Metabolism studies

The R_f values of the standard compounds glyphosate, aminomethylphosphonic acid (AMPA) and glycine on: A) microcrystalline cellulose plates using ethanol, water, ammonia, TCA and acetic acid (Sprankle et al. 1978), and on B) cellulose plates using methanol, water and NaCl (Rageb 1978) are presented in Table 4.

The comparison between the solvent systems using A) ethanol, water, NH_4OH and TCA and B) methanol, water and NaCl shows that the standard compounds were resolved marginally more clearly using solvent system B. There was a very marked difference between the clarity of separation using the 21 day plant extract in solvent systems A and B.

Table 4. Thin-layer chromatographic separation of glyphosate and its potential metabolites.

Compound	R_f values for each solvent system Ethanol: H_2O : NH_4OH : TCA	Methanol : H_2O : NaCl.
Glyphosate	0.25	0.60
Aminomethylphosphonic acid	0.37	0.40
Glycine	0.50	0.44
21 day plant extract	0.50	0.39, 0.63

Using solvent system B, trace quantities of two compounds were identified as aminomethylphosphonic acid (R_f 0.39) and glyphosate (R_f 0.63). The separation of the plant extract using solvent system A was very poor, resulting in a large spot (R_f 0.50) resembling glycine. Autoradiograms produced from the thin-layer chromatograms failed to show any ^{14}C activity except at the origins due to the relatively low amount of radioactivity in the extract.

DISCUSSION

In the field trials, E. arvense has proved to be very variable in its response to any treatment, and generally resistant to glyphosate. For these reasons it is difficult to determine the optimum time for maximum susceptibility of the rhizome system to glyphosate. The greatest reduction in rhizome dry weight was produced from the treatment on 5 August (1977 assessment); however, the 24 June treatment had produced the maximum reduction in the 1978 assessment.

Similarly, no clear pattern emerged from the ^{14}C-glyphosate uptake and translocation studies. Translocation of ^{14}C-glyphosate was noted only in the stems of the 168 h autoradiography treatments on 25 June and 6 August. The quantitative radioassay studies for the 168 h 25 June application indicated that an abnormally high amount of ^{14}C-activity had accumulated only in the treated shoots. Both the autoradiographs and the quantitative radioassays for the 168 h, 6 August application suggested some translocation of ^{14}C-glyphosate from the treated shoots to the untreated shoots and stems.

The treatment dates of 24/25 June and 5/6 August appear to have greater significance than any other dates. It is possible that E. arvense may be most susceptible to a foliar-applied translocated herbicide at the same time as that of another lower plant, bracken, Pteridium aquilinum. During July to early autumn, bracken fronds are fully expanded, herbicide retention is optimal and the rhizome buds act as the main sinks for herbicide accumulation (Veerasekaran et al., 1976). In contrast, the susceptibility of E. arvense treated on 25 June agrees with the growth stage where maximum basipetal translocation of ^{14}C-MCPA took place (Müller, 1970). No clear recommendation can be given on the basis of the available data, but early season treatment with glyphosate should be avoided since a temporary destruction of shoot growth will soon give rise to a great increase in shoot density. Conventional spraying volumes of 400 l/ha have been superior to CDA at 20 l/ha while 3.5 kg a.e./ha glyphosate proved more effective than 2.5 kg a.e./ha.

The metabolism studies identified a useful solvent system (Ragab, 1978) for the thin-layer chromatographic separation of glyphosate and its potential metabolites in E. arvense extracts. The TLC solvent system of Sprankle et al. (1978) lacked resolution in this particular situation and seemed to favour the development of glycine within the extract, at the expense of glyphosate or its metabolites. Using the solvent system of Ragab (1978) intact glyphosate was identified from the 21 day glyphosate-treated E. arvense. Insufficient quantities of the ^{14}C activity were present in the spot however, to produce a TLC autoradiograph. Trace quantities of the glyphosate metabolite, AMPA, in this plant extract could have come from the original glyphosate formulation. Sprankle et al. (1978) reported the presence of small amounts of AMPA within a glyphosate sample. Since there was insufficient ^{14}C to produce a TLC autoradiogram the origin of the AMPA in this situation is in doubt. Further experiments will attempt to determine the extent to which E. arvense might metabolise ^{14}C-glyphosate to yield ^{14}C-AMPA.

In conclusion, the resistance shown by E. arvense to glyphosate cannot be attributed to herbicide metabolism or lack of absorption, but to limited translocation.

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WEED CONTROL PROGRAMME FOR RED BEET

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Summary In the 1978 trial the soil conditions were dry and the weather warm and sunny when the pre-emergence materials were applied and none of them controlled weed growth. In contrast all the post-emergence treatments gave a good weed control. The principle weeds were Chenopodium album, Polygonum aviculare and Spergula arvensis.

The same treatments were applied in 1979 under warm and wet conditions and all treatments containing metamitron virtually controlled all weeds throughout the life of the crop, whereas propham + fenuron + chlorpropham gave a relatively unsatisfactory weed control. The post-emergence treatments were ineffective as shown on the untreated pre-emergence plots (no weed growth on metamitron treated plots pre-emergence to assess them. On the 1979 site the principle weeds were Matricaria spp., Capsella bursa-pastoris and Stellaria media.

Plant stands were not reduced by the chemical treatments in either year. The best pre-emergence herbicide treatments were metamitron or metamitron + ethofumesate which, if applied under moist conditions, will control weeds throughout the life of the crop. Phenmedipham or phenmedipham + ethofumesate were the most effective post-emergence treatments.

INTRODUCTION

The object of the trial was to evaluate the new herbicide metamitron as a pre- and post-emergence herbicide treatment either alone or mixed with ethofumesate or adjuvant oil, in comparison with other Approved pre- and post-emergence materials on main crop red beet.

This followed previous work at the National Vegetable Research Station (Roberts and Bond, 1974, 1975, and 1976) and Stockbridge House Experimental Horticulture Station (Senior, Whitewell and Jones 1978) which suggested metamitron was very safe to the crop and had good herbicidal activity.

Since this trial work was completed metamitron has been approved for use on red beet under the Ministry's Agricultural Chemicals Approved Scheme.

METHOD AND MATERIALS

Soil type: The soil type was a fine sandy loam of the Quarndon series overlying lacustrine clay.

Experimental layout: Four pre-emergence treatments in all combinations with 6 post-emergence treatments in randomised blocks with 3 replicates.

Method and timing of application: The variety Regala (Bejo) sown 17 May 1978 and also 1979.

The herbicides were applied by knapsack sprayer at 840 litre/ha except the phenmedipham and phenmedipham + ethofumesate which were applied by motorised sprayer at 224 litre/ha. The pre-emergence sprays were applied within two days of drilling. All post-emergence treatments were applied on the same day (10 June, 1978 and 15th June 1979) with the crop at the 2-3 true leaf stage.

All other husbandry aspects were similar to good commercial practice. The crop was harvested and recorded for yield and final plant stand on 24th October 1978 and 13th September 1979.

Method of recording: Plant stands were taken on 4 rows x 2 m immediately before the post-emergence treatments were applied to show any phytotoxicity from the pre-emergence treatments, and repeated three weeks later to assess phytotoxicity from the post-emergence treatments. Counts were also made at harvest time.

Percentage weed cover and identification of weed species present plus the proportion of cover attributed to each species were made at suitable intervals.

A month after the post-emergence sprays were applied all plots were hand weeded and the times recorded.

Yield records were taken from 1.5 m x 4 m plot area, in two sizes, under 25 mm (unmarketable) and over 25 mm.

There were no bolters in either year.

RESULTS

Plant stands on 9th June 1978 and 12 June 1978, just before the post-emergence treatments were applied, showed none of the treatments affected plant stand (table 1)

Stand counts were repeated three weeks after the post-emergence treatments were applied and again none of the treatments or combinations significantly affected plant stands (table 2).

Weed assessments were made shortly before the post-emergence materials were applied by estimating the percentage ground covered by the various weed species. In 1978 weed control was poor with C. album, P. aviculare and S. arvensis pre-domin ating, but in 1979 pre-emergence application of metamitron gave almost total weed control throughout the life of the crop (table 3).

The striking difference in weed control between the two seasons can be attributed to moisture difference when the pre-emergence herbicides were applied. In 1979 conditions were ideally moist and weed control with metamitron in particular was superb. Weed assessments approximately 3 weeks after the post-emergence sprays showed the percentage total weed cover (table 4).

In 1978 when the pre-emergence treatments were generally poor, no significant differences in post-emergence materials arose, but it was apparent that ethofumesate gave the best control of C. album. None of the post-emergence sprays effectively controlled P. aviculare.

In 1979 metamitron pre-emergence was so effective that assessments of the post-emergence herbicides on these plots was not required. However, when no pre-emergence sprays were used, it was noticeable that phenmedipham completely controlled S. media, S. vulgaris and C. bursa-pastoris, but failed to control Matricaria spp. Ethofumesate controlled S. media and S. vulgaris but not Matricaria spp.

Hand weeding costs in 1978 were generally no more costly than a herbicide spray, except where no post emergence sprays were used. In 1979 hand weeding costs were very high on all treatments other than where metamitron was used pre-emergence.

Harvesting took place on 20th October 1978 and 13th September 1979 and the yield of marketable beet (over 25 mm diameter) for the 4 pre-emergence treatments averaged over all the post-emergence treatments is shown in table 6.

In 1978 there were no significant yield effects from the pre-emergence programmes. In 1979 metamitron outyielded the hand weeded control treatments. Previous trials have shown the crop safety of metamitron used either pre- or post-emergence. In fact it appears to enhance crop growth compared to other treatments. The effect of the post-emergence treatments is given in table 7.

In 1978 the metamitron post-emergence treatment and the hand weeded control plots outyielded the other four treatments. Ethofumesate applied post-emergence visibly checked the crop, cupping the leaves and causing the foliage to turn darker red. The plants outgrew the symptoms after 3-4 weeks. All treatments except metamitron reduced yields in comparison to the control.

In 1979 there were no significant yield differences between the post-emergence treatments but again the trend showed that metamitron had enhanced crop growth. In both years no significant differences in plant numbers per treatment occurred, so yield differences were due to increased root size.

DISCUSSION

Weed control in red beet is expensive and crop output relatively low, but clean crops are easier to harvest and a good herbicide is required to lower costs of production.

Under moist favourable conditions metamitron applied pre-emergence provides virtually weed-free conditions throughout the life of the crop as it did in the 1979 trial. It is also the safest material to use post-emergence (Stockbridge House Annual Report, 1977) and enhances crop growth.

Ethofumesate as an additive to metamitron or phenmedipham gave the best control of C. album but it checked the plants and in 1978 reduced yields.

In 1978 the post-emergence sprays performed well, but in 1979 when the most prevalent weeds were Matricaria spp. C. bursa-pastoris and S. media they were ineffective.

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Table 1

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

Pre-emergence treatment	1978 9 June	1979 12 June
propham + fenuron + chlorpropham	18.83	38.66
metamitron + ethofumesate	19.90	39.65
metamitron	19.44	38.63
control	20.50	39.00
SED (d.f. 66)	1.408	1.272

Table 6

Yield (tonnes/ha) of roots over 25 mm diam.

Year	propham + fenuron + chlorpropham	metamitron + ethofumesate	metamitron	control
1978	65.9	64.4	61.9	65.3
		SED (d.f.46) 5.50		
1979	56.2	61.0	64.7	53.6
		SED (d.f.46) 3.26		

Table 7

Yield (tonnes/ha) of roots over 25 mm diam.

Year	metamitron	metamitron + ethofumesate	metamitron + adjuvant oil	phenmedipham	phenmedipham + ethofumesate	control
1978	73.9	53.8	62.2	60.5	57.5	78.5
			SED (d.f. 46) 6.74			
1979	64.7	57.8	58.7	56.9	56.4	58.9
			SED (d.f. 46) 4.00			

Table 2

Mean plant stand/m of single row assessed after post-emergence sprays

pre-emergence	post-emergence: metamitron	metamitron + ethofumesate	metamitron + adjuvant oil	phenmedipham	phenmedipham + ethofumesate	Control
4 July 1978						
propham + fenuron + chlorpropham	15.87	22.58	17.25	15.46	16.37	15.75
metamitron + ethofumesate	19.25	17.29	17.21	15.54	20.62	18.62
metamitron	21.21	19.79	19.96	17.96	15.21	16.21
control	20.75	14.37	20.33	21.67	17.50	22.00
		SED 3.356 (d.f. 46)				
3 July 1979						
propham + fenuron + chlorpropham	39.08	39.29	37.21	39.25	37.71	38.83
metamitron + ethofumesate	41.17	40.83	35.00	39.79	39.04	41.04
metamitron	41.04	40.12	38.08	39.54	32.83	40.37
control	40.50	39.71	38.83	39.79	39.04	38.87
		SED 2.950 (d.f. 46)				

Table 3

Estimated Weed Cover - % of total plot area before post-emergence sprays

Pre-emergence	Chenopodium album	Polygonum aviculare	Spergula arvensis	Stellaria media	Senecio vulgaris	Matricaria spp	Capsella bursa-pastoris	control
1978								
propham + fenuron + chlorpropham	3.8	1.2	0.9	-	-	-	-	5.9
metamitron + ethofumesate	5.5	1.7	1.3	-	-	-	-	8.5
metamitron	6.2	3.2	2.4	-	-	-	-	11.8
control	4.6	1.9	1.2	-	-	-	-	7.7
							SED (d.f.66)	2.658
1979								
propham + fenuron + chlorpropham	0.6	-	-	0.04	0.2	11.2	3.4	14.9
metamitron + ethofumesate	0.0	-	-	0.0	0.0	0.09	0.01	0.1
metamitron	0.0	-	-	0.14	0.0	0.06	0.0	0.2
control	1.1	-	-	5.2	0.5	34.2	16.7	57.2
							SED (d.f.66)	6.26

Table 4

Weeds: % ground cover approximately 3 weeks after post-emergence sprays were applied

	post-emergence						
pre-emergence	metamitron	metamitron + ethofumesate	metamitron + adjuvant oil	phenmedipham	phenmedipham + ethofumesate	control	mean
1978 (27 June)							
propham + fenuron + chlorpropham	8.2	8.0	1.7	2.0	0.7	12.3	5.5
metamitron + ethofumesate	3.7	0.7	1.3	3.0	1.7	2.0	2.1
					d.f. 42	SED	3.27
metamitron	6.0	0.7	3.7	0.3	1.3	41.0	8.8
			SED 8.01 d.f. 42				
control	8.7	0.0	4.3	4.3	2.7	1.8	3.6
mean	6.6	2.3	2.7	2.4	1.6	14.3	
			SED 4.01 d.f. 42				
1979(3rd July)							
propham + fenuron + chlorpropham	13.7	48.3	27.0	7.7	8.3	91.7	32.8
metamitron + ethofumesate	0.0	0.0	0.3	0.0	0.0	0.0	0.1
					d.f. 46	SED	5.91
metamitron	0.0	0.0	0.0	0.0	0.0	0.3	0.1
			SED 14.48 d.f. 46				
control	63.3	80.0	88.3	63.3	71.7	8.3*	62.5
mean	19.3	32.1	28.9	17.7	20.0	25.1	23.9
			SED 7.24 d.f. 46				

* control plots hand weeded on 19 June as very weedy. The low weed count on the three control plots in 1978 (1.8% was purely by chance that few weeds appeared on these areas.

Table 5

Handweeding time (mins/plot) four weeks after post-emergence sprays applied (plot size $10.8m^2$)

	post-emergence						
pre-emergence	metamitron	metamitron + ethofumesate	metamitron + adjuvant oil	phenmedipham	phenmedipham + ethofumesate	control	mean
14th July 1978							
propham + fenuron + chlorpropham	1.67	1.92	2.00	1.92	0.92	5.33	2.20
metamitron + ethofumesate	1.17	1.17	1.31	1.42	1.23	2.31	1.43
			SED 1.167	(d.f. 46)		(d.f.46)	SED 0.476
metamitron	1.67	0.78	1.56	1.06	1.69	9.00	2.60
control	3.50	1.17	2.92	2.58	0.94	2.83	2.30
mean	2.00	1.26	1.94	1.74	1.20	4.87	2.10
			SED 0.583	(d.f. 46)			
12th July 1979							
propham + fenuron + chlorpropham	14.7	31.3	22.6	8.3	15.6	42.7	33.6
metamitron + ethofumesate	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			SED 7.24 (d.f.46)			(d.f.46)	SED 2.96
metamitron	0.0	0.0	0.0	0.0	0.0	0.0	0.0
control	35.2	31.6	49.4	33.7	36.7	61.0*	22.5
mean	12.5	15.7	18.0	10.5	13.1	25.9	
			SED 3.62	(d.f. 46)			

NB 1 min/plot = 15.43 hours/ha
* includes 46 mins on 19 June

WEED CONTROL PROGRAMMES FOR MAIN CROP CARROTS

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Summary There was no significant differences between linuron and chlorbromuron when used as pre-emergence herbicides in main crop carrots. Of the post-emergence treatments compared pentanochlor + chlorpropham + metoxuron consistently gave better results in terms of weed control and yield than chlorbromuron, linuron + metoxuron or linuron alone.

INTRODUCTION

The comparison of the new herbicides, new formulations of older herbicides and new mixtures of herbicides available for use on carrots commenced in 1977 (Senior, et al, 1978). The experiments reported in this paper are a continuation of this work.

METHODS AND MATERIALS

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

Experimental layout: randomised block with 3 replicates. Plot size 1.5 metre by 6 metre.

Experimental treatments: pre-emergence herbicides.
linuron as 50% w.p. at 0.56 kg/ha
chlorbromuron as 50% w.p. at 0.56 kg/ha

post-emergence herbicides:
chlorbromuron as 50% w.p. at 0.56 kg/ha
linuron as 15% e.c. at 0.525 kg/ha + metoxuron as 50% suspension concentrate at 1.75 kg/ha
pentanochlor + chlorpropham as 45% e.c. at 1.35 kg/ha + metoxuron as 50% suspension concentrate at 1.5 kg/ha
linuron as 50% w.p. at 0.56 kg/ha

The combinations of pre- and post-emergence treatments used is shown in the table on results.

In 1978 the crop was sown on 15 May and on the 16th May in 1979, the pre-emergence herbicides being applied one day later. Of the post-emergence herbicides, in 1978 the pentanochlor + chlorpropham + metoxuron mixture was applied on 13 June, the chlorbromuron and linuron on 19th June, and the linuron + metoxuron on 6th July. In 1979 the pentanochlor mixture and the linuron was applied on 20th June, and the chlorbromuron and the linuron + metoxuron on 28th June.

Weed assessments were made just before applying the post-emergence herbicides and again three to four weeks after application. Plant stand counts were made after emergence and again after the post-emergence sprays (record omitted in 1979) and finally at harvest. Time taken to hand weed the biggest weeds not taken by the post-emergence treatments was taken 3-4 weeks after post-emergence application in 1978, but not in 1979.

RESULTS

In neither year did the pre-emergence treatments significantly affect the germination (table 1). The drier soil at planting may have accounted for the slightly lower overall germination in 1978.

Pre-emergence weed control was poor in 1978, even so the difference between linuron and the untreated control reached significance (table 2).

In 1979 under moister soil conditions linuron and chlorbromuron worked well, the difference between both herbicides and the control being highly significant. In neither year was there a significant difference between the two herbicides, though in each year there was a small difference in favour of linuron.

There was no significant effect of the post-emergence herbicides on plant stand in 1978 (table 3). This record was not taken in 1979. However no visual effect was observed in the field in both years, also the plant stands at harvest (table 4) showed no significant differences between any treatment.

The weed control effects from the post-emergence herbicides were more conclusive. In 1978 the percentage ground cover of weeds on plots with pentanochlor + chlorpropham + metoxuron, irrespective of the pre-emergence treatment was significantly less than that on plots receiving any other post-emergence treatment (table 5), whilst the difference in 1978 reached a very significant level. The 1978 result was supported by the time taken to hand weed the plots 4-6 weeks after application of the post-emergence treatments (table 6). Again this record was not taken in 1979.

In 1978 linuron pre-emergence followed by chlorbromuron post-emergence gave a significantly lower yield than the highest yielding treatment which was chlorbromuron pre-emergence, followed by pentanochlor + chlorpropham + metoxuron (table 7). In 1979 the combination of linuron pre-emergence with linuron + metoxuron post-emergence produced the highest yield in the smallest (unmarketable) grade. In the two marketable grades the highest yield was obtained from linuron pre-emergence followed by the pentanochlor + chlorpropham + metoxuron mixture post-emergence, whilst the linuron pre-emergence and chlorbromuron post-emergence, and the linuron pre-emergence and the linuron + metoxuron post-emergence gave significantly lower yields.

DISCUSSION

Over the two years there appears to be no significant difference between linuron and chlorbromuron as pre-emergence herbicides, though only linuron gave significant benefit over the untreated control in 1978 when pre-emergence weed control overall was poor.

The outstanding post-emergence herbicide appears to be the mixture of pentanochlor + chlorpropham + metoxuron. At the dose used it appears to be safe to apply at an early stage of crop growth (first true leaf).

In practice this treatment and linuron w.p. post-emergence were applied 5-10 days earlier than the remaining two post-emergence treatments. Thus they are being applied to smaller more susceptible weeds. Even when no pre-emergence herbicide has been applied, the pentanochlor + chlorpropham + metoxuron has still given very good weed control.

Similarly the yield from this pentanochlor mixture has been the highest following chlorbromuron pre-emergence in 1978 and following linuron pre-emergence in 1979.

References

SENIOR, D., WHITWELL, J.D. and JONES, A.G. Weed control programme for main crop carrots. Proceedings 1978 British Crop Protection Conference - Weeds, 3, 865-868

Table 1

Mean plant stand/m of row - before post-emergence spray

Treatment	13 June 1978	18 June 1979
linuron	56.2	68.4
chlorbromuron	58.2	69.0
control	48.8	67.5
d.f. 18		
SED linuron - control	6.04	2.18
SED linuron - chlorbromuron	4.78	2.15
SED control - chlorbromuron	6.41	2.31

Table

Mean plant stand/m of row: 6.6.78 after post-emergence spray

Pre-emergence treatments	post-emergence treatments: chlorbromuron	linuron + metoxuron	pentanochlor + chlorpropham + metoxuron	linuron
linuron	45.9	57.5	41.6	-
chlorbromuron	-	-	50.3	48.2
control	-	-	45.5	-
	SE 10.94 (d.f. 15)			

Table 4

Plant stand/m^2 at harvest

Year	Pre-emergence herbicides	Post-emergence treatments: chlorbromuron	linuron + metoxuron	pentanochlor + chlorpropham + metoxuron	linuron
1978	linuron	237.5	257.5	223.5	-
	chlorbromuron	-	-	245.5	226.7
	control	-	-	242.0	-
	SED 31.88(d.f. 15)				
1979	linuron	191.1	228.0	223.2	-
	chlorbromuron	-	-	249.0	250.8
	control	-	-	227.0	-
	SED 32.57 (d.f. 15)				

Table 2

Pre-emergence weed control: weed cover as % of total ground area

Year	Pre-emergence treatment	Weeds: Poa annua	Stellaria media	Chenopodium album	Polygonum aviculare	Polygonum persicaria	Polygonum convolvulus	Spergula arvensis	Senecio vulgaris	Total
1978	13th June									
	linuron	0.16	1.53	5.32	16.45	0.00	0.05	12.57	0.88	39.17* (a)
	chlorbromuron	0.00	2.25	19.69	13.61	0.32	1.84	22.78	0.25	50.63
	control	0.00	1.15	8.91	15.09	0.00	6.47	25.88	0.72	57.50

analysis of total weed cover (d.f. 18)
SED linuron - control 7.61 (a) SED chlorbromuron - control 8.071 SED chlorbromuron - linuron 6.016

Year	Pre-emergence treatment	Poa annua	Stellaria media	Chenopodium album	Polygonum aviculare	Capsella bursa-pastoris	Veronica spp.	Others	Total
1979	28th June								
	linuron	0.05	0.00	0.04	0.74	0.00	0.16	0.01	1.00*** (a)
	chlorbromuron	0.08	0.00	0.04	2.41	0.00	0.41	0.06	3.00*** (b)
	control	0.88	2.64	6.90	3.53	41.13	0.73	2.94	58.75

analysis of total weed cover (d.f. 18)
SED linuron - control 2.88 (a) SED chlorbromuron - control 8.071 (b) SED chlorbromuron - linuron 6.016

Key to levels of significance in all tables

(P=0.05)* (P=0.01)** (P=0.005)***

Table 5

% ground cover by weeds 3-4 weeks after post-emergence sprays

Year	Pre-emergence Treatments	Post-emergence treatments: chlorbromuron	linuron + metoxuron	pentanochlor + chlorpropham + metoxuron	linuron
23rd July 1978					
	linuron	22.50	11.25	2.25*	-
	chlorbromuron	-	-	0.75*	11.25
	control	-	-	2.25*	-
		SED 2.666 d.f. 15			
16th July 1979					
	linuron	0.50***	0.00***	0.00***	-
	chlorbromuron	-	-	0.00***	1.25*
	control	-	-	2.00	-
		SED 0.3140 d.f. 15			

Table 6

Time (minutes) taken to hand weed plots

Year	Pre-emergence Treatments	Post-emergence treatments: chlorbromuron	linuron + metoxuron	pentanochlor + chlorpropham + metoxuron	linuron
28th	linuron	2.87	2.29	0.63*	-
July	chlorbromuron	-	-	0.50*	3.94
1978	control	-	-	0.75*	-
		SED 1.035 d.f. 15			

Table 7

Total marketable yield (tonnes/ha)

Year	Pre-emergence Treatments	Post-emergence treatments: chlorbromuron	linuron + metoxuron	pentanochlor + chlorpropham + metoxuron	linuron
1978	linuron	44.32	52.77	51.50	-
	chlorbromuron	-	-	56.57	52.47
	control	-	-	50.32	-
		SED 3.064 d.f. 15			
1979	Yield less than 19 mm (unmarketable) tonnes/ha				
	linuron	4.12	5.588**	4.31	-
	chlorbromuron	-	-	4.54	4.83*
	control	-	-	4.35	-
		SED 0.409 d.f. 15			
	Yield 19.32 mm (best marketable grade) tonnes/ha				
	linuron	46.12*	43.62*	42.46	-
	chlorbromuron	-	-	47.79	51.25
	control	-	-	47.92	-
		SED 2.646 (d.f. 15)			
	Yield over 19 mm (total marketable) tonnes/ha				
	linuron	66.04*	63.34**	77.0	-
	chlorbromuron	-	-	72.5	74.7
	control	-	-	71.2	-
		SED 3.80 (d.f. 15)			