THE EFFECT OF SOME MECHANICAL FACTORS ON THE PLACEMENT AND HERBICIDAL ACTIVITY OF ASULAM SPRAYS

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Summary Laboratory and field experiments have shown that some mechanical factors associated with sprayer performance have a profound effect on the placement and subsequent herbicidal activity of asulam against wild oats (*Avena fatua*). Variation in boom height, spraying pressure and nozzle type affected activity and in some cases resulted in well defined zones of weed control. In most cases such zones could be correlated with the quantity of spray retained by *Avena fatua* and with spray distribution, although other factors such as spray droplet size may be implicated.

Résumé Des éssais en laboratoire et en plein champ ont demontré que quelques facteurs mecaniques de concert avec les méthodes de pulvérisation ont un effet determinant sur la "disposition" de l'asulame et par la suite sur son activité herbicide contre la folle avoine (*Avena fatua*). Des variations de la hauteur de la rampe, de la pression et du type de buse utilisé se firent ressentir et dans quelques cas résulterent en zônes de contrôle définies de mauvaises herbes. Dans la plupart des cas de telles zônes pourraient être mises en corrélation avec la distribution du liquide pulvérisé ainsi qu'avec la quantité retenue par *Avena fatua*. Toutefois d'autres facteurs tels que la dimension des gouttelettes vaporisées peuvent être impliqués.

INTRODUCTION

It has long been recognised that the biological activity of foliage applied herbicides can be affected by a number of application factors. These include formulation, spray volume and droplet size. Pre-occupation with the detailed operation of these factors may obscure the overriding need to achieve effective herbicide placement under field conditions. Field application techniques are not ideal and our understanding of 'effective placement' is very limited.

Correct placement is becoming increasingly important with the growing sophistication of chemical weed control techniques. Nowhere has this been more marked than in the case of herbicides for post-emergence control of *A. fatua*. This is because -

(a) The chemicals are generally less selective towards crops such as cereals and flax, than herbicides used against broad-leaved weeds.

(b) Control of *A. fatua* is often attempted under conditions of poor crop competition and high weed density. Thus even a minor reduction in weed control will be obvious and likely to lead to appreciable yield depression (Friesen 1972).

Placement of any herbicide is influenced by several factors, the most important of which are formulation and application method. The composition of herbicide formulations is determined by biological experiment and takes into account many other factors (Foden 1972). During development, sufficient control of herbicide application is exercised to ensure efficient use. No such control can be exercised over commercial spraying.

The present work examines the extent to which certain spraying factors affect the placement and activity of low volume sprays of asulam applied to A. fatua.

METHOD AND MATERIALS

Spray pattern studies

The spray characteristics of four types of commercial nozzle tips were examined using a 10 ft wide spray jet patternator. The nozzles tested were Spraying Systems 'Tee-jets' 6501 and 65015 and Monarch 32 and 39M fan jets. These jets are designed to deliver volumes of approximately 5 gal/ac for the smaller jets (6501 and 32M) and 10 gal/ac for the larger (65015 and 39M) at appropriate tractor speeds.

The jets tested on the patternator were used in the field experiment described below. A record of the 'ground deposits' in this experiment was obtained by incorporating the dye Standacol Red 2G in the spray solution, and spraying a strip of white paper laid across the plot. Preliminary patternator experiments gave similar results for aqueous dilutions of asulam plus wetter, with or without Standacol Red. Greenhouse experiments showed that the dye had no effect on the activity of asulam plus wetter against A. fatua.

Included angles of sprays were measured from high speed photographs (Fig. 2).

Tests on commercial sprayers

Commercial ground crop sprayers in Canada and the U.K. were fitted with calibrated pressure gauges at a number of points in the hydraulic system. The results of these tests are given in Table 1.

Field experiment - U.K.

A pure drilled stand of A. fatua was sprayed with solutions containing a commercial formulation of asulam plus wetter ('Asulox' F) plus 1% w/v Standacol Red 2G. Spraying was carried out when the wild oat was 10-12 in high using a single wheeled ground-crop sprayer. The direction of spraying was at right-angles to the rows of wild oat.

The three jets used in this experiment were kept in the same relative positions along the spray boom, as in the patternator tests. Jet spacing was 20 in.

Calibration of the sprayer showed that the volume of spray delivered varied with jet type and operating pressure. Spray solutions were made up so that the concentration of asulam was equivalent to a dose rate of 1 lb a.i./ac in the volume delivered at 40 lb/in^2 for each jet type. The appropriate solution was sprayed at three different pressures (10, 20 and 40 lb/in^2 - measured at the jet) and two different boom heights 22 in above ground level (12 in above the plants) and 22 in above the plants.

After spraying, whole plant samples were cut at soil level, from four points across each plot. The quantity of dye retained by the plants was estimated colorimetrically using an adaptation of the method described by Hibbitt (1969). From this data it was possible to calculate the quantity of asulam retained by the plants.

Three weeks after spraying an assessment of weed control was made. As expected, control was uneven across most plots; therefore, both plant height and the width of controlled and uncontrolled areas was measured. The product of these two dimensions was used as a measure of both controlled and uncontrolled weed bulk. In Table 2 the controlled "bulk" is expressed as a percentage of the total bulk. Values given are the means of three replicate plots per treatment. The percentage controlled bulk values were correlated with spray pattern and herbicide retention data.

Figure 1 - Mechanical factors affecting spray placement

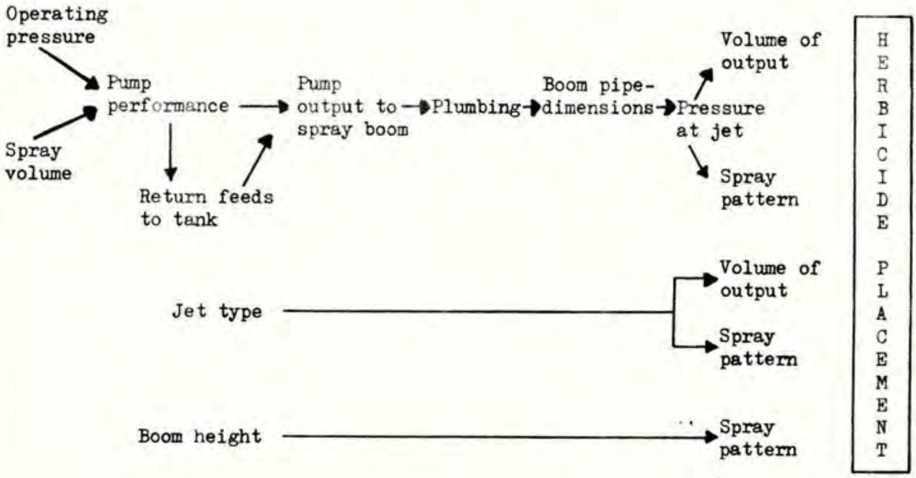

Figure 2 - The effect of hydraulic pressure on angle included by fan jet spray

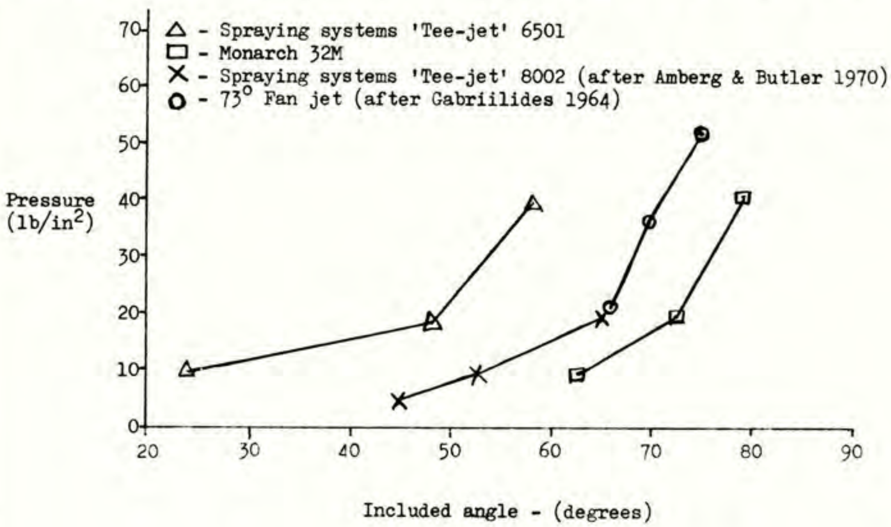

Table 1 - Hydraulic pressure measurements on commercial sprayers

Sprayer	Jets	Output (gal/min) over length of boom tested	Single boom length (ft)	Pressure (lb/in^2) At gauge fitted near pump	At first jet on boom	At last jet on boom
1 U.K.	Red Flat fan	3.1	21	30	23	15
				40	31	21
				50	40	25
2[a] U.K.	No. 4 Hollow cone	4.5	15	10.6	8	4.8
		10		52	34	20
3[b] U.K.	No. 40 Flat fan	3.2	12	38	28	20
				48	35	25
4 Canada	Spraying Systems 6502 Flat fan	2.8	27	30	22	-
				40	30	30
				50	38	38
				55	40	39
5 Canada	Spraying Systems 6502 Flat fan	2.4	23	30	28	27
				40	38	38
				45	40	40
				50	45	45

a - N.I.A.E. Test Reports for Users No. 378 (1964)

b - N.I.A.E. Test Reports for Users No. 377 (1964)

Figure 3 - The effect of hydraulic pressure and jet distance from target, on spray distribution

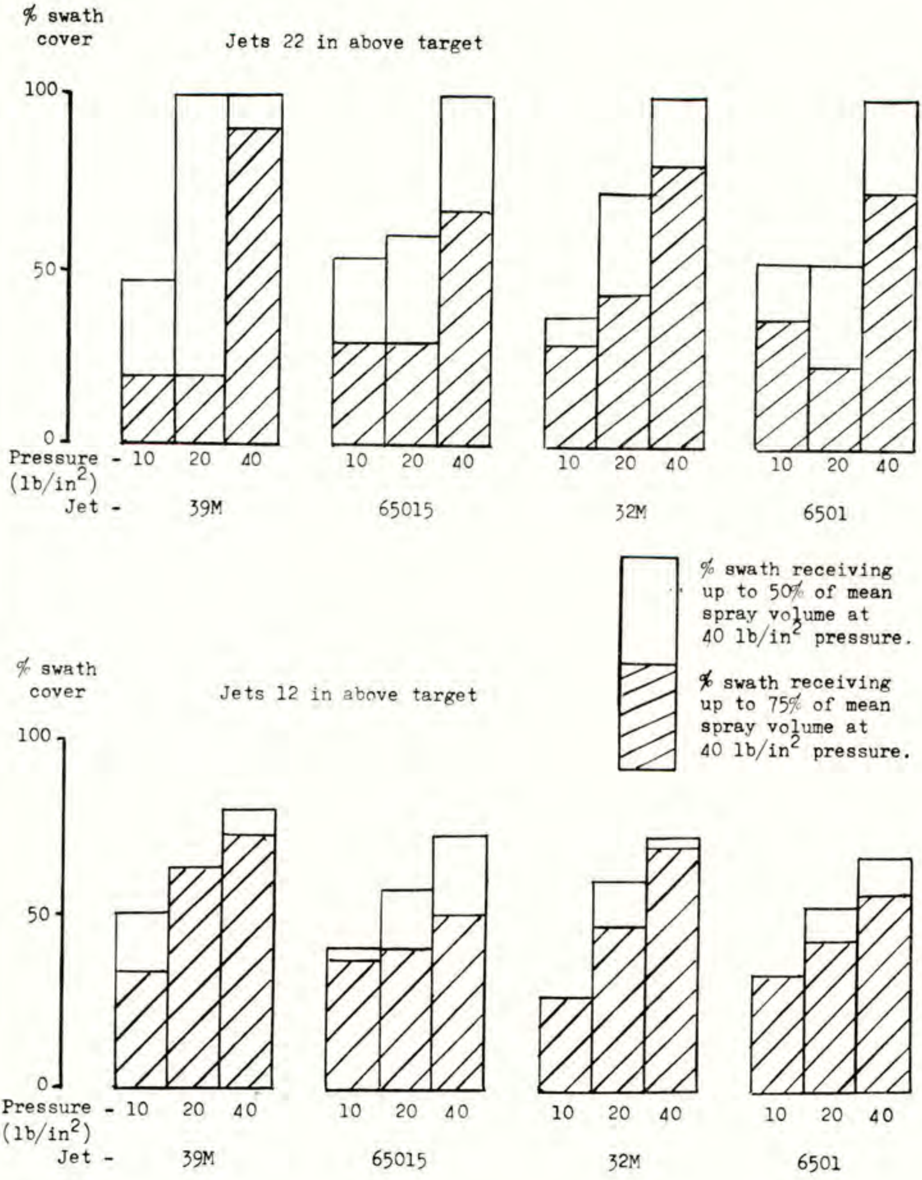

Table 2 - The effect of some mechanical factors on the retention and herbicidal activity of asulam sprays applied to *Avena fatua* - Field experiment

Fan Jet	Distance above plants (in)	Pressure lb/in^2	% swath receiving up to 75% of spray volume delivered at 40 lb/in^2	% "controlled" plant bulk	µg asulam retained per g plant
Monarch 39M	22	10	20	8	51
		20	20	15	69
		40	90	100	114
Spraying Systems 65015	22	10	30	13	59
		20	30	32	78
		40	67	100	117
Monarch 32M	22	10	30	16	60
		20	43	27	78
		40	80	61	140
Spraying Systems 6501	22	10	37	24	59
		20	23	17	91
		40	73	100	133
Monarch 39M	12	10	33	22	43
		20	63	21	60
		40	73	55	88
Spraying Systems 65015	12	10	37	17	51
		20	40	19	67
		40	50	100	98
Monarch 32M	12	10	27	29	46
		20	47	48	71
		40	70	70	91
Spraying Systems 6501	12	10	33	24	46
		20	43	34	91
		40	57	100	121

Dose rates - 1 lb asulam plus 0.1 lb wetter per acre.

All spray solutions contained 1% w/v Standacol Red 2G.

Avena fatua - Pure stand - 10-12 in high - tillering

Correlation coefficients (22 d.f.)
Weed control/spray distribution = 0.7741 ***
Weed control/spray retention = 0.8172 ***
Spray distribution/spray retention = 0.7421 ***

DISCUSSION

Figure 1 shows some of the mechanical factors which affect herbicide spray placement. These factors influence both the amount of spray applied and the horizontal distribution of spray across the swath.

Nation (1968) and Speelman and Janssen (1974) have reported considerable variation in the spray patterns laid down by ground crop sprayers. This has been attributed to poor nozzle performance and vibration of the spray boom. Tractor speed and roughness of terrain contributed to the variation caused by boom movement.

Other workers have demonstrated the effect of hydraulic pressure and boom height on swath pattern. Rice (1967) showed that spray pattern was disturbed by lowering the boom, resulting in a series of peaks and troughs in spray deposit compared with the pattern obtained at the correct height. Gabriilides (1964) demonstrated zoning of spray pattern resulting from changes in boom height or hydraulic pressure. Spray booms are often lowered to reduce spray drift, although Kepner et al (1972) state that lowering the boom adversely affects the uniformity of the spray pattern.

Tests on commercial ground crop sprayers have shown that pressure measured at the jet may differ from that indicated by the gauge mounted on the equipment. The causes of this pressure drop are connected with pump performance, 'plumbing' of the machine and spray boom dimensions (Fig. 1).

When fan jets operate at sub-optimal pressures the angle included by the spray is diminished (Fig. 2) resulting in a reduction of spray overlap between adjacent jets. In extreme cases there may be a gap in the spray pattern. Reduced spray angle and the concurrent fall in fluid output, as pressure is lowered, results in a striking reduction in the efficiency of spray distribution (Fig. 3). Where spray was applied at a pressure of 20 lb/in^2, in all but one case at least half the sprayed area received less than 75% of the intended volume of spray. Lowering the boom to 12 in above the target tended to improve spray cover at low pressure (narrow angles) but impaired distribution at 40 lb/in^2 (wide angle). These effects were largely independent of jet type and output.

The results of a field experiment designed to test the practical significance of these observations are given in Table 2. Many of the treatments resulted in clearly defined zones or strips of controlled weed adjacent to zones where the growth of *A. fatua* was almost unchecked.

The high degree of correlation between spray distribution across the swath, percentage controlled plant bulk and quantity of spray retained by the plants show that jet pressure and, to a lesser extent, boom height were of paramount importance in determining herbicidal activity.

In comparison with Monarch jets, weed control using Spraying Systems jets at 40 lb/in^2 was less adversely affected by lowering the boom. Spray retention data also indicates that the Spraying Systems jets were slightly more efficient.

Examination of spray deposits on the paper strips suggested that sprays produced by Monarch jets were coarser than from Spraying Systems jets. Lake and Taylor (1974) showed greenhouse grown *A. fatua* to be more susceptible to barban sprays applied as 100 μ diameter droplets than as 220 or 440 μ diameter droplets. The effect of spray droplet size on the activity of asulam has yet to be investigated, but may prove to be similar.

There are clearly many interactions among spray placement factors which affect the herbicidal activity of asulam. The present work emphasises the need to take these factors into account as well as those arising from mainly biological considerations (Hibbitt et al 1974).

Acknowledgments

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NOTES

NOTES

THE EFFECT OF SPRAYING LARGE PLOTS OF NUPHAR LUTEA (L.) (YELLOW WATER-LILY) WITH GLYPHOSATE

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Summary. An experiment was set up to assess the effect of spraying large plots of Nuphar lutea (yellow water-lily) with glyphosate. The plots were sprayed with 1 and 2 kg a.i./ha in 180 l/ha water. Parallel swaths of 4 m width were sprayed and an untreated strip 0.3 m wide was left between them. The results, assessed one year after treatment, showed that a dose of 2 kg/ha gave better than 99.9% control while the lower dose of 1 kg/ha gave about 98% control. There was no visible evidence of plants growing in the untreated strips in the plot treated at 2 kg/ha while in the loser treatment the surviving plants tended to be in these strips.

INTRODUCTION

Under suitable conditions Nuphar lutea forms dense stands of both floating and submerged leaves. These can restrict the use of water for recreational activities and can reduce the water carrying ability of drainage systems. The use of herbicides to control this species has, so far, been limited to the application of 2,4-D amine to the floating leaves (Robson 1973). This has had only limited success and several applications are necessary before the growth of the plant is significantly reduced. However, when considering alternative methods of control, applications of a herbicide to the floating leaves are preferable to treating the water as a whole from the point of view of economy, safety and selectivity.

Glyphosate has also been shown to be active against Nuphar lutea (Barrett 1974a) and in experiments in which small plots were sprayed with various doses of glyphosate 0.75 kg a.i./ha and above caused significant reduction in the numbers of floating leaves in the season following treatment. However, it was considered probable that where large plots were sprayed, involving more than one swath, the passage of the sprayer through the water would submerge the floating leaves and therefore leave tracks of untreated leaves between the spray swaths. Most plants produce several floating leaves and because of the long leaf petiole they tend to spread out occupying available water surface and the laminas may be some distance apart. It is possible that some leaves from each plant would receive a dose of herbicide although others might not be sprayed either because they were submerged by the sprayer or screened by other leaves. Where this occurs control would depend on whether enough herbicide is intercepted by the remaining leaves to kill the rhizome. In order to determine whether glyphosate would give satisfactory control of Nuphar lutea when untreated tracks were left between spray swaths an experiment was set up in which a large area of Nuphar lutea was sprayed.

METHOD AND MATERIALS

The experiment was set up in a lake near Oxford in part of which was a dense stand of Nuphar lutea growing in water 0.3 to 0.6 m deep. The Nuphar lutea extended from the shore towards the centre of the lake where it had an irregular outline about 30 m from the shore. Because of this irregular outline the two adjacent plots selected were not of identical size. Plot I had an area of 1382 m^2 and plot II was 2292 m^2.

Using a floating spray-rig (Barrett 1974b), parallel swaths were sprayed leaving an untreated track of 0.3 m in width between swaths. Plot I was treated with glyphosate at 1 kg a.i./ha in 180 l/ha water, this being considered near the minimum lethal dose, and plot II was treated at 2 kg a.i./ha in the same quantity of water. The spraying rig moved from the centre of the lake to the shore on each spraying run. It was then pulled into the lake centre again down the same line before being moved along to spray the next parallel swath. The untreated strip, left between swaths, was the width of the polystyrene float on the end of the spray boom where it passed over the leaves. In plot I eleven spray runs were necessary to cover the whole plot while in plot II there were twenty-six spray runs. The treatments were applied on the 2nd and 3rd August 1973 in sunny calm conditions.

The spray nozzles used in this experiment were "Spraying Systems 8001" nozzles and the operating pressure was 0.83 bar.

Before treatment the population of floating Nuphar lutea leaves was sampled using a 1 m^2 floating quadrat and leaves wholly or partly within the quadrat were counted. Random samples of slightly over 1% of the total area of each plot were taken. A second sample of similar size was taken one year after treatment together with a sample from an adjacent untreated area.

RESULTS

The first assessment was made on the 26th and 27th July 1973 before the treatments were applied. The results of this assessment are shown in Table 1.

Table 1

The numbers of floating leaves in July 1973

	Plot I	Plot II
Total area of plot	1382 m^2	2292 m^2
Area sampled	17 m^2	28 m^2
Percentage of total	1.23 %	1.22 %
Mean number of leaves/m^2	55.4	31.9
Total number of leaves per plot (estimated)	76600 ± 2500	73100 ± 2450

Plot I was slightly over half the size of plot II but contained more leaves. The density of leaves in terms of numbers/m^2 in plot II was 57.6% that in plot I.

A second assessment was made on the 10th July 1974 when in addition to sampling on the same basis as before, it was also possible to count the total number of floating leaves in each plot.

Table 2

The numbers of floating leaves in July 1974

	Plot I	Plot II
Total area of plot	1382 m^2	2292 m^2
Area sampled	18 m^2	28 m^2
Percentage of total	1.3 %	1.22 %
Mean number of leaves/m^2	0.94	0
Total number of leaves/plot (estimated)	1300 $\pm$ 310	0
Total number of leaves/plot (by counting)	1715	27

When the second assessment was made on 10th July 1974 a count was also carried out on an adjacent untreated area and, from a sample of 5 m^2, a mean of 47.2 leaves/m^2 was obtained. No flowers were recorded in either treated plot on the second assessment but there was a mean of 1 flower/m^2 in the untreated area.

After the treatments were applied on 2nd and 3rd August 1973 visual observations were made on the experiment at intervals until the autumn when natural dieback occurred in untreated areas. The effect of the higher dose became visible within two weeks. By September there were clean tracks through the water-lilies where the spray had fallen on the floating leaves but at this stage the unsprayed strips showed no sign of dying off. The lower dose of 1 kg/ha had little effect on the floating leaves in 1973 and it was not possible to distinguish the lines of the sprayed swaths.

Visual observations on the submerged leaves in 1974 showed that they had gone from plot II indicating that glyphosate had completely killed the rhizomes. In plot I, where a few floating leaves remained, the submerged leaves were on the same rhizomes as the floating leaves but were absent from the rest of the plot.

DISCUSSION

The results, assessed one year after treatment, showed that glyphosate at a dose of 2 kg/ha gave complete control and at 1 kg/ha the regrowth was reduced by about 98%. A few of the surviving plants in plot I were in the treated swaths but the majority were in the lines of the unsprayed strips.

The leaves in this lake were fairly small, particularly where they were tightly packed together in plot I. The approximate mean leaf area was 100 cm^2, therefore a dose of 1 kg/ha would be equivalent to a dose of 1 mg of herbicide per leaf. In initial trials (unpublished) this was found to be the minimum dose necessary to kill the growing point on the rhizome. The screening effect of one leaf lying on top of another and the strips which were not sprayed probably left some plants in plot I with insufficient herbicide on their leaves to kill the rhizome. In plot II the leaves were more spaced out with less overlapping so that, although there were twice as many untreated strips in this plot as in plot I, the higher dose of glyphosate killed almost all the plants.

In the early stages of development small laterals are formed which do not produce floating leaves. Since there were no submerged leaves in plot II there is an indication that the glyphosate was not only translocated down to the main growing point on the rhizome but also was directly or indirectly responsible for the death of any lateral branches.

As a result of this experiment it was concluded that satisfactory control of

Nuphar lutea may be obtained by doses of glyphosate of 1 kg/ha. However, where the leaves are densely packed together or where there is a risk of submerging leaves during the spraying operation the higher dose of 2 kg/ha will produce slightly better results.

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TRIALS WITH TERBUTRYNE FOR THE CONTROL OF AQUATIC WEEDS

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Summary In 13 trials with terbutryne as a wettable powder or granule formulation 0.05 mg/l in treated water gave control of these algae: Cladophora spp., Enteromorpha intestinalis and Rhizoclonium spp. 0.1 mg/l is required for the control of Vaucheria dichotoma. At 0.05 mg/l a number of submerged and floating vascular weeds were also controlled. Polygonum amphibium was resistant and Potamogeton natans was only suppressed. Treatment of substantial amounts of weed resulted in de-oxygenation of the water but by using a granule formulation before substantial growth occurred existing weed was controlled and terbutryne persisted to kill later weed growth. Terbutryne appeared to have no adverse effect on water fauna in the trials when applied before weed growth occurred.

Résumé 13 essais effectués avec du terbutryne appliqué sous forme de poudre mouillable ou de granules, ont permis d'établir qu'à la dose de 0.05 mg/l d'eau traitée, la propagation des algues suivantes est maîtrisée: Cladophora spp., Enteromorpha intestinalis et Rhizoclonium spp. La dose de 0.1 mg/l s'est avérée necessaire pour juguler Vaucheria dichotoma, tandis que 0.05 mg/l suffisaient à endiguer la propagation d'un nombre de mauvaises herbes aquatiques vasculaires, flottantes et submergées. Polygonum amphibium s'est, par contre, révélé resistant au traitement et la propagation de Potamogeton natans ne fut que freinee. Le traitement de quantités substantielles de mauvaises herbes s'est traduit par la desoxygènation de l'eau mais l'emploi du produit sous forme de granules, avant que la pleine croissance n'ait eu lieu, a permis de maîtriser la propagation des mauvaises herbes existantes tandis que l'action herbicide persistante du terbutryne suffisait à l'éradication de toute croissance ultérieure des mauvaises herbes. Lors des essais, le terbutryne semble n'avoir eu aucun effet contraire sur la faune aquatique lorsqu'il fut appliqué avant la periode de croissance des mauvaises herbes.

INTRODUCTION

Field trials in Holland by Van der Weij et al (1971) showed that the differing concentrations of several compounds required to give an equivalent effect on aquatic weeds were as follows: diuron 0.4 mg/l, atrazine 1.6 mg/l, ametryne 0.2 mg/l, terbutryne 0.1 mg/l. Thus terbutryne was 16 times more active than atrazine and twice as active as ametryne, the methylthio analogue of atrazine.

Johannes et al (1973) concluded from 40 trials in Germany that the following doses were required for equal control of aquatic weeds: diuron 1.0 mg/l, simazine 1.6 mg/l, terbutryne 0.025 mg/l. Terbutryne, therefore, was 64 times more active than simazine and 40 times more active than diuron.

In the German trials the herbicides were applied as wettable powders in April before weed growth commenced or in August when weed growth was present. Filamentous algae were controlled by terbutryne at 0.005 mg/l and a wide range of fully submerged vascular plants were controlled at 0.05 mg/l. Plants with floating leaves were generally less sensitive than those which were completely submerged. Emergent species were not controlled by terbutryne at the concentrations required for control of floating and submerged species.

The effect of terbutryne on filamentous algae, reported in these trials, is of special interest in the United Kingdom in view of reports of increasing problems with these species. Most vascular aquatic weeds can be controlled with currently recommended aquatic herbicides but Robson (1973) could make no recommendations for the control of Vaucheria dichotoma, Spirogyra spp. and Enteromorpha intestinalis and listed only one herbicide, diquat, for control of Cladophora spp.

As a result of Continental results a programme of trials was carried out in the U.K. during 1972 and 1973 in which terbutryne was evaluated for the control of aquatic weeds in still and slow moving water.

MATERIALS AND METHODS

A 50% wettable powder of terbutryne was used in the early trials and was compared in later trials with a granule formulation containing 1% terbutryne based on Fullers Earth.

In 1972 six unreplicated trials were laid down for control of weeds in still or sluggish water. Three of the sites were drainage ditches namely: Rookery Farm, Cambridge; Well Creek, Cambridge and Dymchurch, Kent. Two sites were enclosed lakes namely: Hengrave Hall, Suffolk and Littlehampton, Sussex and the sixth site at Elstow, Bedford consisted of a group of concrete storage tanks each with a capacity of 500,000 litres of water. At all six sites a suspension of terbutryne wettable powder was sprayed onto the water surface to give a concentration of 0.05 mg/l a.i. At one site, Rookery Farm, an adjacent ditch was treated at a dose of 0.1 mg/l. All sites, except the lakes, had adjoining untreated stretches of water which were considered as controls.

The granule formulation was used at one site, Elstow, in 1972 and in a further seven unreplicated trials in 1973, at Infields Farm, Cambridge; Binnimoor Fen, Cambridge; Stonea, Cambridge; Dymchurch, Kent; Well Creek, Cambridge; Stonea Grange, Cambridge and Fleetwood, Lancashire. Granules were applied using a motorised knapsack granule applicator at 6 out of the 7 sites treated in 1973. At the other, Well Creek, a boat mounted swinging arm granule spreader was used.

No satisfactory method of physically measuring the amount of weed present could be devised and weed control was assessed subjectively one to three months after treatment as satisfactory or not satisfactory adopting standards of judgment of a potential commercial user.

Because of the interelationship between aquatic weed growth and dissolved oxygen, measurements were made with a portable EIL dissolved oxygen meter at intervals after treatment with terbutryne. Effects on water fauna were assessed after treatment with terbutryne at the Cambridge and Bedford sites by collaborating River Board biologists.

RESULTS

In the 1972 trials the wettable powder formulation of terbutryne gave a satisfactory control of submerged and floating weeds as shown in Table 1.

Filamentous algae and most species of vascular plants occurring in the trials were controlled by 0.05 mg/l terbutryne but Polygonum amphibium was consistently tolerant.

Table 1

Weed control with 0.05 mg/l terbutryne (wettable powder) in 1972 trials 6 weeks after treatment

Weed species \ Location and date treated	Well Creek 9 June	Dymchurch 9 May	Rookery Farm 19 May	Hengrave Hall 26 May	Littlehampton 21 July	Elstow 14 July
Submerged and floating vascular weeds						
Callitriche stagnalis	-	-	S	S	-	-
Ceratophyllum demersum	NS	-	-	-	-	-
Elodea canadensis	S	S	-	-	-	-
Hippuris vulgaris	-	-	-	NS	-	-
Hottonia palustris	-	-	S	-	-	-
Lemna minor & L. trisulca	S	S	-	-	-	-
Polygonum amphibium	-	NS	NS	NS	-	-
Potamogeton pectinatus	S	S	S	-	S	-
Ranunculus aquatilis	-	S	-	-	-	-
Filamentous algae						
Cladophora spp.	S	-	-	-	-	-
Enteromorpha intestinalis	S	S	S	-	-	-
Rhizoclonium spp.	-	-	-	-	-	S

S = satisfactory control   NS = not satisfactory control

Dissolved oxygen measurements were made at 3 sites. At two sites there was a dense growth of weeds at the time of treatment which were 26 May and 9 June respectively and severe de-oxygenation occurred. At Rookery Farm where weed growth was light there was little depletion of oxygen as shown in Table 2.

Table 2

Percentage saturation of oxygen at intervals after treatment with terbutryne (wettable powder) in 1972 trials

Location	Date treated	Dose of terbutryne (mg/l)	Days after treatment 0	7	14	21
Hengrave Hall	26 May	0.05	175	34	52	45
		Untreated	-	161	140	106
Well Creek	9 June	0.05	177	7	24	5
		Untreated	-	180	180	150
Rookery Farm	19 May	0.05	178	148	114	169
		0.1	180	157	143	163
		Untreated	-	>200	150	170

It was concluded from these trials that although terbutryne gave good control of a number of aquatic weeds the de-oxygenation encountered when high plant densities occurred was unacceptable and an alternative method of treatment would be necessary.

The most suitable way of overcoming this problem was found to be a granule formulation of terbutryne. This formulation is applied before weed growth becomes dense and releases terbutryne over a period of time to kill later weed growth.

The first comparison of wettable powder and granule formulations was made in July 1972 in the concrete storage tanks at Elstow which were infested with *Cladophora* spp. The amount of chemical applied was calculated to give the same concentration of terbutryne in the water in each tank. Fourteen days after treatment the granule formulation was found to have a higher concentration of chemically determined terbutryne than the wettable powder formulation (Table 3). This was reflected in the duration of weed control. The tank containing wettable powder became reinfested 84 days after treatment whilst the granule treated tank did not become reinfested until 112 days after treatment.

Table 3

Concentration of terbutryne in mg/l at intervals after treatment with 0.1 mg/l a.i. as wettable powder or granule formulations at Elstow on 14 July 1972

Days after treatment	Wettable powder	Granule
3	0.10	0.05
7	0.12	0.14
14	0.08	0.13
21	0.06	0.10
28	0.04	0.08
56	0.04	0.06
84	< 0.01	0.02
112	-	0.01

The weed control obtained with the granule formulation in 1973 was equal to that obtained with the wettable powder in 1972. Two species, *Ceratophyllum demersum* and *Hippuris vulgaris* which were difficult to control in the 1972 trials, were well controlled by the granule formulation in 1973 (Table 4).

Polygonum amphibium and *Potamogeton natans* appeared to be tolerant of 0.05 mg/l terbutryne. At Stonea Grange *Myriophyllum spicatum* and *Elodea canadensis* were well established at the time of treatment and were suppressed but not eliminated by the terbutryne.

Vaucheria dichotoma was not well controlled at any of the sites where it occurred. Similar results have been reported by Robson *et al* (1974) who found that 0.1 mg/l terbutryne was necessary to give control of this alga.

Table 4

Weed control with 0.05 mg/l terbutryne (granules) in 1973 trials 8 weeks after treatment

Weed species \ Location and date treated	Infields Farm 2 May	Binnimoor Fen 2 May	Stonea 11 May	Dymchurch 22 May	Well Creek 5 June	Stonea Grange 12 June	Fleetwood 7 May
Submerged weeds							
Ceratophyllum demersum	-	-	-	-	S	-	-
Elodea canadensis	-	-	S	S	S	sup	-
Hippuris vulgaris	-	-	S	-	-	S	-
Hottonia palustris	-	S	-	-	-	-	-
Myriophyllum spicatum	-	S	S	S	S	sup	-
Potamogeton pectinatus	S	-	S	S	S	-	-
Ruppia maritima	-	-	-	-	-	-	S
Floating weeds							
Callitriche stagnalis	-	S	S	S	-	S	-
Lemna gibba	-	-	-	-	S	-	-
Lemna minor	-	-	-	S	S	-	-
Potamogeton natans	-	-	-	NS	-	-	-
Polygonum amphibium	-	-	NS	-	-	-	-
Ranunculus aquatilis	-	S	-	S	S	-	-
Filamentous algae							
Cladophora spp.	-	-	-	S	S	-	-
Enteromorpha intestinalis	S	S	-	S	S	-	-
Vaucheria dichotoma	-	sup	NS	-	sup	NS	-

S = satisfactory control   sup = suppressed
NS = not satisfactory control

At Binnimoor Fen and Stonea weed was not extensive when treated and oxygen levels were not severely reduced. The very low oxygen content at Binnimoor Fen after 28 days was due to discharge of farm effluent into the channel. At Well Creek and Stonea Grange, however, weed growth was well advanced when treated and unacceptably low dissolved oxygen levels were recorded as shown in Table 5.

In none of the trials was any visual adverse effect on water fauna observed. A severe reduction in oxygen levels was recorded at Stonea which caused temporary distress to fish. Robson et al (1974) have also reported no indication of toxicity to water fauna at the same doses in their trials but observed similar effects on fish where severe de-oxygenation occurred following treatment.

Table 5

Percentage saturation of oxygen at intervals after treatment with granule formulation of terbutryne

Location	Date treated	Dose of terbutryne (mg/1)	Interval after treatment in days					
			0	7	14	21	28	35
Binnimoor Fen	2 May	0.05	200	-	72	62	34	60
		Untr.	-	-	72	60	14	60
Stonea	11 May	0.05	160	65	-	64	85	120
		Untr.	-	160	-	148	85	140
Well Creek	5 June	0.05	135	16	34	33	28	-
		Untr.	-	80	132	90	12	-
Stonea Grange	12 June	0.05	140	14	75	95	-	-
		Untr.	-	132	180	180	-	-

DISCUSSION

Terbutryne at 0.05 mg/l gave good control of a number of submerged and floating water weeds. Polygonum amphibium was resistant and Potamogeton natans which has floating leaves was only suppressed and was not controlled at this dose. The results also show that at 0.05 mg/l terbutryne gives good control of many filamentous algae including Cladophora spp., Enteromorpha intestinalis and Rhizoclonium spp. Vaucheria dichotoma was only suppressed at 0.05 mg/l and 0.1 mg/l was necessary for control. The absility of terbutryne tocontrol filamentous algae not controlled by existing chemicals is an advance in aquatic weed control. In commercial usage during 1974 good control of algae and submerged and floating vascular weed has been obtained.

Application of terbutryne to dense weed growth resulted in severe de-oxygenation of the water but this was avoided by early application before most weed growth occurred. The use of a granule formulation killed existing weed when applied early and gave control of later weed growth. This reduced the de-oxygenation hazard whilst giving satisfactory weed control.

On visual examination terbutryne used at doses of up to 0.1 mg/l did not greatly affect levels of fauna in the water. The granule formulation of terbutryne has provisional clearance under the U.K. Pesticide Safety Precautions Scheme for use in or near water.

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FIELD TRIALS WITH CYANATRYN (WL63611) FOR THE CONTROL OF AQUATIC WEEDS

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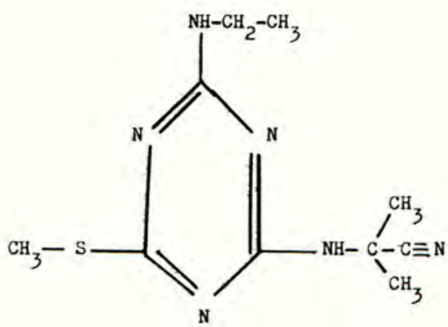
Summary Cyanatryn was evaluated as an aquatic herbicide in 46 field trials carried out in a variety of watercourses and under a range of conditions. Wettable powder, granule and pellet formulations were tested in this work and of these the 10% slow release pellets were found to be the most convenient and suitable for use in both static and slowly flowing water. At nominal doses in the range 0.05-0.5 ppm, cyanatryn gave a consistently good control of many submerged vascular plants and algae in static water. In flowing water a method of calculating the effective dose from the rate of flow and cross sectional area is reported.

INTRODUCTION

Cyanatryn is the common chemical name of the triazine herbicide 2-(4-ethylamino-6-methylthio-s-triazin-2-yl)amino-2-methyl propiontrile.

Structural formula:



Toxicity:

Mammals		LD 50 mg/kg	
Rat	Acute oral toxicity	597	technical material
Rabbit	Acute percutaneous toxicity	> 2,000	" "
Birds			
Mallard duck	Acute oral toxicity	> 2,000	" "
Fish		96h exposure LC 50 ppm	
Rudd		> 25	
Tench		> 25	
Harlequin		10-12.6	
Trout		2.4	
Amphibia			
Tadpoles of common frog		~30	
Invertebrates			
Daphnia longispina at 24h exposure		15.4	

Larvae of Leptophlebia sp. (mayfly) at 168h exposure to 5 ppm showed no effect.

The snails Biomphalaria glabrata and Lymnaea peregra at 168h exposure to 10 ppm showed no effect.

Larvae of Aedes aegyptii (mosquito) at 168h exposure to 10 ppm showed no effect.

Cyanatryn is a highly effective aquatic herbicide which is a specific inhibitor of photosynthesis, causing aquatic plants to live on their reserves for the duration of exposure to the critical concentration. Susceptible plants are eventually starved and die (Payne 1974).

Studies of its effect on aquatic ecosystems and eventual fate are reported elsewhere (Crossland and Elgar 1974 and Roberts 1974).

Effectiveness against a range of submerged aquatic weeds and algae was first demonstrated in glasshouse jar tests in 1971 and 1972 (Payne 1974 and Robson 1974) and further laboratory work confirmed its high algicidal activity (Eaton 1973 and 1974).

METHODS AND MATERIALS

The formulations of cyanatryn used were 50% wettable powder, 1% and 10% granules and 10% pellets. Rates of use are expressed as ppm of active ingredient in treated water. Sites were located all over England in order to cover as representative a range of conditions as possible. They included drains or dykes, ponds and lakes, as static or slowly flowing water situations.

The dimensions of trial lengths were taken before treatment, and in static water dosages were calculated by a simple volumetric method and applications made along the whole length in which treatment was required. In later trials in slowly flowing water, the rate of flow was used to calculate the dose which was then applied to a short stretch above the length to be treated. Flow rates were determined by injecting a small cloud of fluoroscein sodium dye below water level and timing its movement over a one metre length.

The type of formulation determined the method of application. Knapsack sprayers and motorised granule applicators were used for the wettable powder and granule formulations respectively. The most convenient method of applying the pellet formulation was broadcasting by hand.

Mud samples and dissolved oxygen readings were taken prior to treatment at each site, and at 2 sites (trials 4 and 12) daytime dissolved oxygen levels were monitored at regular intervals. Water samples for residue analysis were also taken at regular intervals from trials 41, 42 and 43.

In the trials in static water the nominal concentrations applied ranged from 0.025-0.2 ppm in 1972; 0.05-0.2 ppm in 1973; and 0.1-0.2 ppm with one application at 0.5 ppm in 1974. In later trials using the 10% slow release pellet formulation in slowly flowing water, rates were calculated to give a mean concentration over 14 days of 0.05 ppm (Osgerby 1974).

Estimates of the percentage volume of water infested by weeds were made prior to treatment and at various intervals following treatment.

Details of the trials carried out during 1972, 1973 and 1974 are set out in Table 1.

RESULTS

Table 2 sets out the percentage control obtained at each site. For clarity not more than three main species are mentioned, however the number of occurrences is indicated in Table 3.

Table 3

Weed susceptibilities

Susceptible to 0.1 ppm nominal dose		Susceptible to 0.2 ppm nominal dose		Susceptible to 0.05 ppm mean aqueous phase conc^{n}.	
Vaucheria spp.	(9)	Myriophyllum spicatum	(16)	Myriophyllum spicatum	(3)
Cladophora spp.	(5)	Elodea canadensis	(6)	Elodea canadensis	(3)
Spirogyra sp.	(1)	Potamogeton pectinatus	(14)	Potamogeton crispus	(3)
Enteromorpha intestinalis	(13)	Ceratophyllum demersum	(3)	Potamogeton pectinatus	(3)
Chara sp.	(3)	Callitriche stagnalis	(9)	Ceratophyllum demersum	(3)
Nitella sp.	(1)	Lemna minor	(4)	Callitriche stagnalis	(4)
Potamogeton crispus	(4)	Lemna polyrrhiza	(2)	Vaucheria spp.	(2)
Ranunculus aquatilis	(8)	Oenanthe silaifolia	(1)	Enteromorpha intestinalis	(5)
Zannichellia palustris	(2)	Veronica catenata	(3)	Hippuris vulgaris	(1)
				Ranunculus aquatilis	(1)
				Lemna minor	(1)
				Potamogeton berchtoldii	(1)

Table 1

Site Details

	Trial no.	Location	Flow in m/h	Formulation	Dose in ppm	Treatment date
1972	1	Mid Kent	Static	50% w.p.	0.05	6/4
	2	N. Kent	"	" "	0.05,0.1	12/4
	3	Wilts.	"	" "	0.2	26/4
	4	S. Kent	"	" "	0.1,0.2	2/5
	5	S. Kent	"	" "	0.1,0.2	22/5
	6	S. Kent	"	" "	0.1,0.05	22/5
	7	S. Kent	"	" "	0.2	25/5
	8	S. Kent	"	" "	0.025,0.05,0.1	1/6
	9	Wilts.	20	" "	0.2	13/6
	10	Wilts.	v. slight	1% & 10% gran.	0.2	19/7
	11	S. Kent	Static	50% w.p. and 1% & 10% gran.	0.1	25/7
	12	S. Kent	"	50% w.p.	0.2	31/7
	13	Wilts.	v. slight	" "	0.1	9/8
1973	14	S. Kent	Static	10% granules	0.1,0.2	21/5
	15	Essex	15	10% pellets	'0.05'	22/5
	16	Somerset	Static	" "	0.2	11/6
	17	Somerset	"	" "	0.2	11/6
	18	S. Kent	"	10% granules	0.1,0.2	12/6
	19	S. Kent	15	10% pellets	0.2	18/6
	20	S. Kent	Static	" "	0.2	18/6
	21	S. Kent	v. slight	" "	0.2	20/6
	22	Wilts.	v. slight	" "	'0.05'	25/6
	23	Lancs.	Static	10% granules	0.1	28/6
	24	Lancs.	"	" "	0.1	28/6
	25	S. Kent	"	10% pellets	0.1,0.2	3/7
	26	Bucks.	"	10% granules	0.05	9/7
	27	Cambs.	"	" "	0.1	13/7
	28	S. Kent	15	10% pellets	0.2	13/8
	29	Cambs.	Static	" "	0.1	24/8
	30	N. Kent	120	" "	'0.05'	10/9
	31	S. Kent	Static	" "	0.2	12/9
1974	32	Cambs.	Static	10% pellets	0.2	9/4
	33	Lancs.	60	" "	'0.05'	10/4
	34	Cambs.	Static	" "	0.2	22/4
	35	Lincs.	28	" "	'0.05'	26/4
	36	Lincs.	Static	" "	0.05,0.2	29/4
	37	Cambs.	"	" "	0.2	2/5
	38	Cambs.	65	" "	'0.05'	3/5
	39	Somerset	Static	" "	0.2	7/5
	40	Cambs.	"	" "	0.2	9/5
	41	S. Kent	"	" "	0.1	16/5
	42	S. Kent	"	" "	0.1	20/5
	43	S. Kent	90	" "	'0.05'	20/5
	44	Cambs.	26	" "	'0.05'	23/5
	45	Herts.	Static	" "	0.2	28/5
	46	Cambs.	"	10% pellets	pellets @ 0.2 and 0.5	11/7

('0.05' denotes mean aqueous phase concentration as opposed to nominal concentration)

Table 2

Weed Control

Trial no.	Comments
1	100% kill of Spirogyra sp. but growth of Ceratophyllum demersum at later date.
2	30% and 75% kills of Callitriche stagnalis at 0.05 and 0.1 ppm respectively.
3	100% control of Chara vulgaris. Effect displaced due to water movement.
4	100% control of C. stagnalis and Potamogeton pectinatus at 0.1 and 0.2 ppm.
5	100% control of Myriophyllum spicatum and P. pectinatus at 0.1 and 0.2 ppm.
6	100% and 60% control of M. spicatum at 0.1 and 0.05 ppm respectively.
7	100% control of M. spicatum and Elodea canadensis.
8	Merger of treatments to give 100% control of P. pectinatus.
9	No control due to flow.
10	90% reduction of total weeds estimated but assessment obscured by Lemna spp.
11	Spread of treatment effects.100% kill of P. pectinatus by granules, 80% by w.p.
12	90% control of M. spicatum. Spread of effect.
13	100% control of C. vulgaris.
14	100% " of M. spicatum & Vaucheria spp.Polygonum amphibium suppressed 0.2 ppm
15	100% " of M. spicatum, C. demersum and Enteromorpha intestinalis.
16	100% " of P. pectinatus and Elodea spp.
17	100% " of P. pectinatus and Elodea spp.
18	100% " of Ranunculus aquatilis by both rates.
19	Partial effect which was displaced by flow.
20	Water movement resulted in poor kill.
21	100% control of P. pectinatus and E. intestinalis.
22	100% " of total weeds (inc. Potamogeton berchtoldii) for 1 km.
23	Incomplete effect due to replacement of water by pumping.
24	Incomplete effect due to replacement of water by pumping.
25	Water removed before control effected.
26	Hippuris vulgaris unaffected by rate used.
27	E. intestinalis was effectively controlled despite pumping at 4 days.
28	100% control of C. stagnalis.
29	E. intestinalis was effectively controlled despite pumping at 4 days.
30	80% control of C. stagnalis (high flow rate).
31	100% control of R. aquatilis and C. demersum.
32	Development of Vaucheria spp. prevented but C. demersum grew at later date.
33	100% control of C. stagnalis, M. spicatum and Potamogeton crispus.
34	100% control of C. stagnalis and P. crispus.
35	100% control of M. spicatum and H. vulgaris.
36	100% control of E. intestinalis.
37	100% control of Vaucheria spp.
38	100% control of Cladophora and Vaucheria spp.
39	100% control of C. stagnalis, Zannichellia palustris and Veronica catenata.
40	No control
41	100% control of M. spicatum and P. pectinatus.
42	100% control of M. spicatum and Vaucheria spp.
43	100% control of C. stagnalis and P. crispus.
44	100% control of E. intestinalis.
45	Early treatment prevented development of Vaucheria spp.
46	100% control of C. stagnalis and Z. palustris except by 0.2 ppm pellets.

The growth of Potamogeton natans and Polygonum amphibium was suppressed and these species can be considered moderately tolerant to trial doses. Little or no effect was apparent against Nuphar lutea and Glyceria fluitans in any of the trials. With the exception of Oenanthe silaifolia which was completely controlled by nominal doses of 0.2 ppm, emergent weeds such as Phragmites communis and Typha spp. were unaffected by applications to the water in which they were growing.

Complete weed control generally occurred 4-6 weeks after treatment, although algae sank to the bottom after a few days due to a lack of buoyant oxygen. There was little or no regrowth during the remainder of the year of treatment and in many instances the effects of treatment resulted in a minimal growth the following year.

General susceptibility groupings of weeds are shown in Table 3, but under certain circumstances different susceptibilities applied. In those static trials carried out where the water was impounded and not subject to movement, effective control was obtained by doses of half the level shown (trials 1, 4, 6, 14, 41, 42). The small cross sectional area and peaty profile of trial 40 probably contributed to the poor performance at this site and increased doses are necessary under these conditions. The effectiveness of a nominal dose of 0.5 ppm and the ineffectiveness of a nominal dose of 0.2 in a similar dyke was demonstrated in trial 46.

In trials 23, 24 and 25 lack of control was due to pumping shortly after treatment. This resulted in a replacement of water, a problem common to the use of many aquatic herbicides.

Dissolved oxygen as % saturation in trials 12 and 4 is shown in figures 1 and 2. From this work it appears that the dissolved oxygen falls for the first few days after treatment, then remains fairly constant for 2-3 weeks before rising again to a high level 4-5 weeks after treatment.

Residue levels from trials 41, 42 and 43 are shown in Tables 4 and 5.

Table 4

The analysis of static water and mud for residues of cyanatryn following an application of 10% slow release pellets at a nominal dose of 0.1 ppm

Trial 41			Trial 42	
Sampling interval in days from application	Water (mg/litre)	Mud (mg/kg) wet weight	Sampling interval in days from application	Water (mg/litre)
2	0.01	-	2	0.01
6	0.01	-	4	0.02
8	0.015	-	8	0.025
12	0.015	-	11	0.03
15	0.02	-	14	0.04
18	0.02	-	21	0.04
25	0.02	-	28	0.03
32	0.02	-	65	0.02
69	0.01	0.025	87	0.015
91	<0.01	0.04		
110	<0.01	0.03		

Figure 1

Graph to show variations in dissolved oxygen following treatment in trial 12

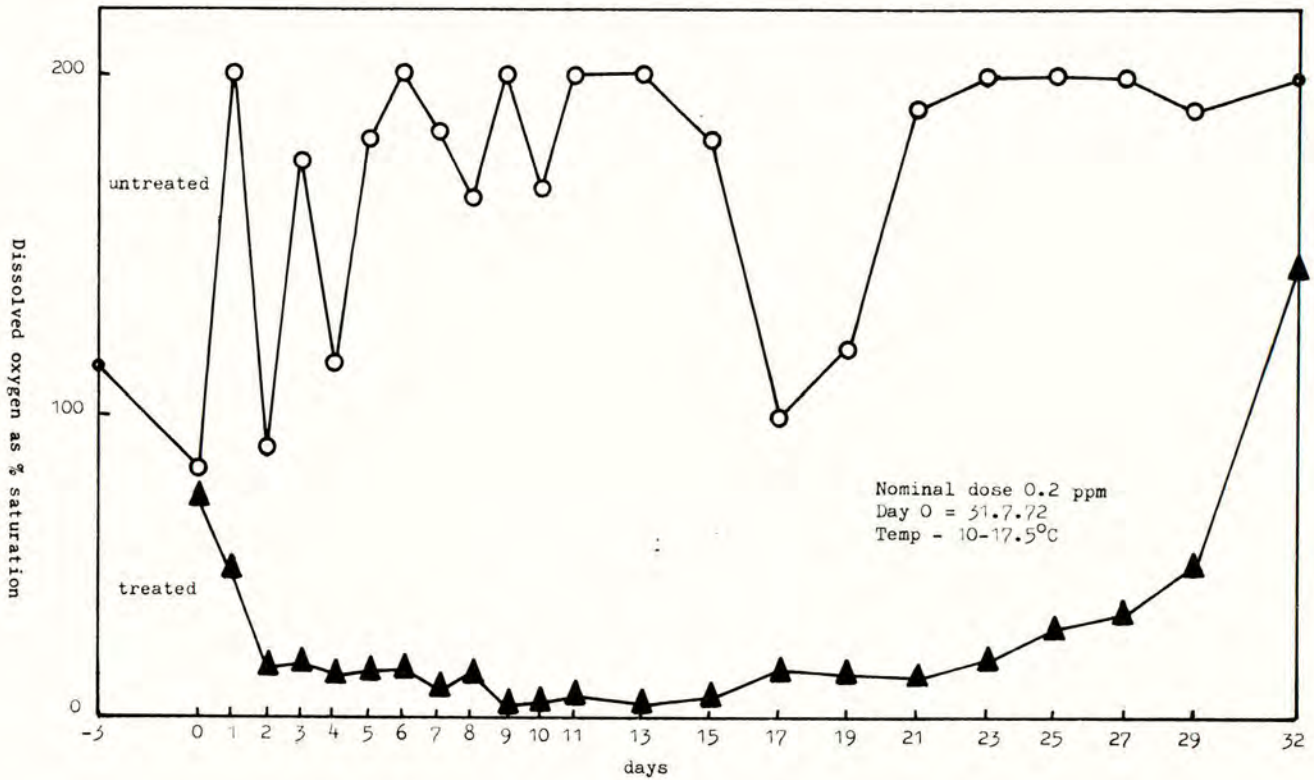


Figure 2

Graph to show variations in dissolved oxygen following treatment in trial 4

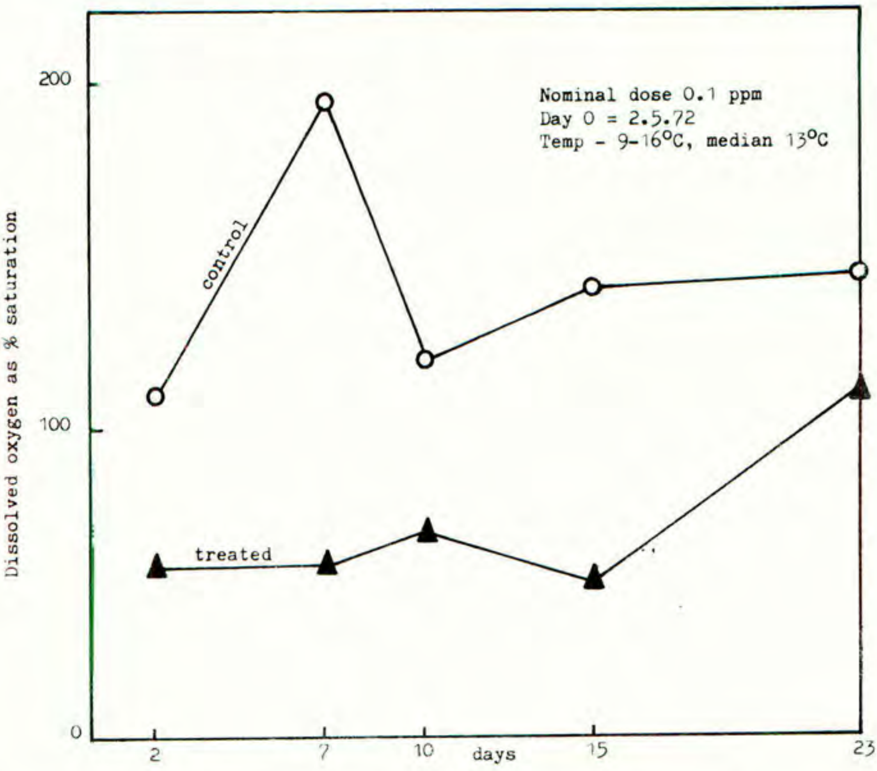


Table 5

The analysis of flowing water for residues of cyanatryn following treatment with 10% pellets calculated to give a mean concentration of 0.05 ppm for 14 days

Trial 43 (Flow rate 90 m/h)

Sampling interval in days from application	Residues (mg/litre) Distance between application and sampling points (m) 50	500	1000	2080
2	0.11	0.08	> 0.01	>0.01
4	0.08	0.05	0.06	>0.01
8	0.09	0.06	0.045	0.04
11	0.07	0.04	0.05	0.045
14	0.07	0.04	0.04	0.045
21	0.03	0.02	0.025	0.03
28	0.04	0.015	0.02	0.02

DISCUSSION

Cyanatryn was shown to be effective against a wide range of aquatic plants. The species most susceptible were those without roots (algae) and those with a poorly developed root system or proportionately small reserves of food. Those plants such as Potamogeton natans and Polygonum amphibium which have better developed root systems are less susceptible, while those emergent plants such as Phragmites communis and Typha spp. with well developed root systems and large reserves are least susceptible.

Algal species were quickly and effectively controlled (trials 27 and 29), and although a good control of Lemna spp. was demonstrated in impounded water situations, its mobility under flowing conditions often obscured the result (trial 10). Ceratophyllum demersum was not well controlled by treatments made earlier in the year while it was still dormant (trials 1 and 32), although excellent results were obtained from later applications (trials 15 and 31).

The w.p. formulation gave very effective control in most trials, but as a result of its solution in water it is subject to displacement in any movement. This occurred at trials 3 and 8. Its inadequacy under conditions of slight flow were demonstrated in trial 9. It was hoped to overcome displacement effects with the use of granule formulations. Although their use resulted in an improvement they did not solve the problem (trial 11). With the development of a 10% slow release pellet there was a further improvement in effect. Further trials with this formulation (trials 19 and 20) confirmed previous work which had indicated that it was necessary to treat static and flowing water in different ways. A dose giving a mean aqueous phase concentration over 14 days of 0.05 ppm was found to be very effective in slowly flowing water, and the following equation was used to calculate the amount required.

$$a.m. = A \times V^{-1}$$

where a.m. = active material in kg
V = velocity of the water in km/day
A = cross sectional area of the channel in sq.m

The slow release of cyanatryn by this formulation is well demonstrated in Table 5. The chemical, which has been shown in the laboratory to have a half life of 27 days in water, is required to be present at a phytotoxic concentration for at least 14 days to control aquatic weeds. This slow release enables a lower initial dose to be employed than would otherwise be necessary. In the static site 4 the persistence is due to the slow release formulation used.

The residues in mud are not taken at the beginning of the period because of the danger of contaminating the sample with a pellet which has not degenerated. Table 4 indicates a retention of only about 5%-10% of the total dose applied. Any material escaping from the mud into the water at a later date would be broken down normally.

The oxygen tensions monitored in trial 4 did not fall to as low a level as in trial 12. Applications in trial 4 were made early in the season before weed infestation became severe and indicate the importance of early applications in order to avoid low oxygen tensions. However, both trials demonstrate the recovery in dissolved oxygen levels after 3 weeks.

The effectiveness of cyanatryn as an aquatic herbicide in controlling both algae and submerged vascular plants, coupled with the low residues and ease of application of the 10% pellets, make this formulation a potentially useful tool in the management of any static or slowly flowing water system.

Acknowledgements

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FURTHER STUDIES ON THE SEASONAL CHANGES IN THE SUSCEPTIBILITY OF SOME EMERGENT WATER PLANTS TO DALAPON

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Summary. The emergent water plants Carex riparia (Curt), Sparganium erectum L. and Phragmites communis Trin. were sprayed with dalapon at various times during the growing season. The effects, assessed by shoot counts one year after treatment, showed that Carex riparia was susceptible to dalapon at 22.4 kg/ha between the end of May and the beginning of October. Cutting the shoots did not affect regrowth.

Phragmites communis was susceptible from the earliest date of spraying (7th July) to mid October but there was an indication that it was most susceptible when sprayed in August and September. Cutting the shoots had no significant effect on the regrowth.

Sparganium erectum was also susceptible to dalapon at 22.4 kg/ha applied in late June and late July but the reduction in regrowth following sprays in May and September was not significant. At 11.2 kg/ha dalapon the best results were obtained spraying in July.

Only at one treatment date in one of the experiments with Sparganium erectum did cutting show any reduction in regrowth the following year.

INTRODUCTION

Previous experiments on the water plants Carex riparia Curt., Typha angustifolia L. and Glyceria maxima (Hartm) Holmberg, have shown that the susceptibility of these plants to dalapon increases during the growing season and reaches a peak in August or September (Barrett and Robson 1971).

For further studies on the seasonal changes in susceptibility to dalapon three species with differing growth patterns were chosen. The first, Carex riparia, flowers early in the spring and its leaves remain green until late in the season. It may also overwinter without dieback. Sparganium erectum L. begins growth considerably later than Carex riparia. It flowers between July and early September (Cook 1962) and dies back as autumn frosts occur. Phragmites communis Trin. also emerges later than Carex riparia and flowers in late August or early September (Haslam 1972). Dieback may not occur until late October or November.

METHOD AND MATERIALS

Three experiments are described. One on Phragmites communis and one on Sparganium erectum were carried out on pure stands of the test species. The third experiment was on a mixed stand of Carex riparia and Sparganium erectum and the effects of the treatments were assessed on each species separately.

All the experiments were designed as randomised blocks with three or four replicates and all plots were 4.57 m in length and either 2 m or 4 m wide.

The formulation of dalapon used contained 74% a.e. of the sodium salt of 2,2-dichloropropionic acid without surfactant or additives. Applications were made with an Oxford Precision Sprayer using a 2 m boom with four fan nozzles spraying vertically down onto the foliage and delivering 4.2 l/m. The forward speed was adjusted to apply the spray at the rate of 675 l/ha.

To compare the effects of the herbicide with complete defoliation by a non herbicidal treatment a cutting treatment was included in which shoots were cut at their base at the same time as each herbicide treatment was applied.

In all the experiments the effects of the treatments were assessed in the year after application by cutting the shoots at ground level in 0.8 m^2 quadrats and returning them to the laboratory for counting. The quadrats were placed in the centre of each plot or swath where two swaths were used. To facilitate this the dead shoots were cut and removed from all plots during the winter after treatment.

RESULTS

Experiment I Phragmites communis

The site chosen for this experiment was a ditch near Chettisham, Ely which contained water during the winter but was normally dry during the summer months. It was about 400 m long and about 2 m wide at the top with steep sides shelving to the bottom which was about 1 m wide. A vigorous, dense population of Phragmites communis was growing in the bottom and on the sides of the ditch. The dalapon (22.4 kg/ha) and cutting treatments were applied on five dates during 1970.

Assessments were made on the regrowth on 31st August 1971, the year following treatment and on 7th September 1972, two years after treatment. In both cases shoots were counted on 0.8 m^2 in the bottom of the ditch in the centre of each plot.

Table 1

The log mean number of shoots/m^2 of Phragmites communis in August 1971

Treatment date		Dalapon at 22.4 kg/ha	Cutting	Control
		Treatments		
7 July	1970	0.71 (5.1)	1.95 (89.0)	
30 July	"	0.20 (1.6)	1.70 (50.0)	
18 August	"	0.16 (1.4)	1.77 (58.9)	1.87 (84.1)
24 September	"	0.32 (2.9)	1.96 (91.2)	
13 October	"	0.98 (4.9)	1.97 (93.3)	
S.E.D. 0.171		(anti log in brackets)		

Dalapon gave good control at all the treatment dates although it was less effective at the first and last dates.

Table 2

Number of shoots of Phragmites communis/m^2 in September 1972

Treatment dates		Treatments		
		Dalapon at 22.4 kg/ha	Cutting	Control
7 July	1970	106.4	143.8	
30 July	"	29.0	86.7	
18 August	"	52.6	122.3	99.3
24 September	"	87.0	132.5	
13 October	"	114.5	129.8	
S.E. 24.41				

There was considerable variation between replicates after two years which may have been caused by re-invasion by rhizomes of untreated plants growing from the sides and ends of the plots. There was no significant difference in shoot numbers between the treatments although there was an indication that the July and August dalapon treatments were still showing some effects.

Experiment II Sparganium erectum

In two experiments on Sparganium erectum dalapon was applied at 11.2 kg/ha to one and at 22.4 kg/ha in the other. The first experiment was sited in a stream near Cricklade in Wiltshire which was about 4 m wide and contained a pure stand of Sparganium erectum growing from bank to bank. Four treatment dates were chosen to cover the growing season of the plant (Table 3). On each date dalapon was sprayed at 11.2 kg/ha in a 2 m swath from each bank and in the cutting treatment shoots were cut off at the base of the stem.

Table 3

The mean number of shoots of Sparganium erectum/m^2 on 21st July 1971

Treatment dates		Treatments		
		Dalapon at 11.2 kg/ha	Cutting	Control
8 June	1970	65.1	47.9	
21 July	"	15.0	12.2	49.4
28 August	"	27.2	58.7	
16 September	"	63.0	62.0	
S.E. 13.87				

Both dalapon and cutting treatments in July 1970 caused a significant reduction in regrowth in the following season and not at any of the other dates.

Experiment III Sparganium erectum and Carex riparia

The site for this experiment was a ditch near Bridgewater in Somerset, in which there was a mixed stand of Sparganium erectum and Carex riparia. The treatments of dalapon at 22.4 kg/ha and cutting the shoots at ground level were applied on four dates during the growing season. Shoots were counted in the season after treatment.

Table 4

The mean number of shoots of Carex riparia and Sparganium erectum/m^2

on 27 July 1971

Treatment date	Carex riparia			Sparganium erectum		
	Dalapon at 22.4 kg/ha	Cutting	Control	Dalapon at 22.4 kg/ha	Cutting	Control
19 May 1970	8.6	68.7	64.4	18.7	47.5	30.8
25 June "	1.4	71.5		0.9	32.9	
29 July "	1.4	75.8		0.4	39.9	
22 Sept "	2.9	38.8		14.3	42.2	
	S.E. 18.3			S.E. 7.82		

Dalapon significantly reduced the regrowth of Carex riparia at all dates and also reduced the regrowth of Sparganium erectum when applied in June or July. Cutting had no significant effect on either species at any of the four treatment dates.

In both the experiments on Sparganium erectum there was less regrowth when the shoots were sprayed in July and August than in treatments applied earlier or later in the season. The higher dose of 22.4 kg/ha gave better control than the lower dose and appeared to be effective over a greater period of the growing season.

DISCUSSION

Phragmites communis was susceptible to dalapon at all the treatment dates and there was an average reduction in shoot numbers of 92.3% one year after treatment compared with the control. The first treatment (7 July 1970) was delayed so that late emerging shoots would be sprayed. Earlier treatments would miss more shoots and may be less effective. The effectiveness of treatments applied late in the season may depend on the weather. Early frosts causing the shoots to die back before the dalapon had been fully translocated to the rhizome system would reduce the effectiveness of these treatments.

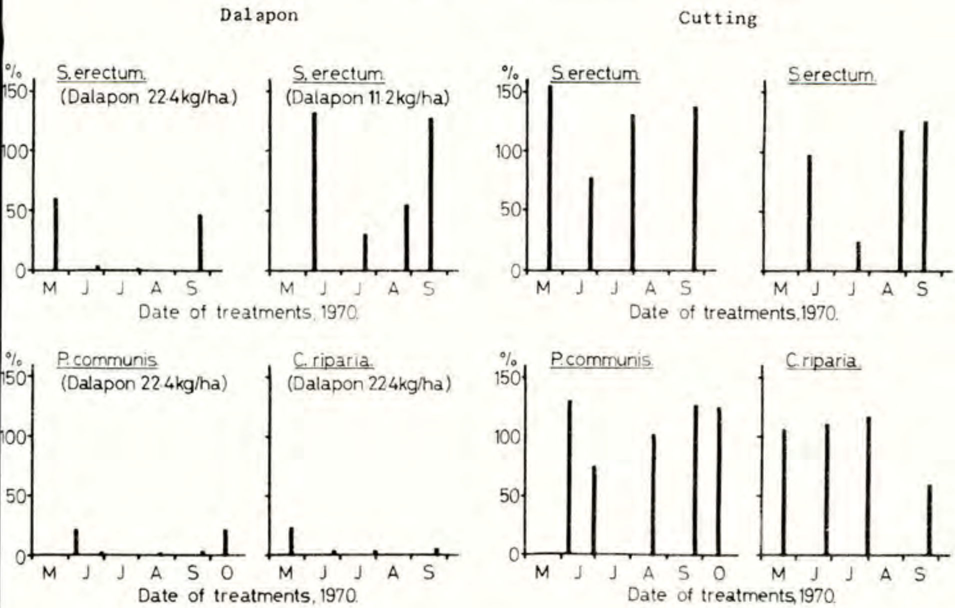
In our previous work (Barrett and Robson 1971) we found that Carex riparia was not susceptible to dalapon at 22.4 kg /ha when sprayed while flowering in April. The work reported here indicates that it becomes susceptible in May and may be controlled if sprayed at any time from then until the end of September.

Sparganium erectum was most susceptible to dalapon in late June, July and August although a dose of 11.2 kg/ha was not sufficient to give satisfactory control even at the time of greatest susceptibility.

In figure I the effects of the dalapon and cutting treatments have been expressed in terms of shoot numbers as a percentage of control in the year after treatment. Only in the experiments on Sparganium erectum was there any

Fig. 1

The number of shoots in 1971 as a percentage of the control



significant difference between the dalapon treatments and in this case dalapon at 22.4 kg/ha was most effective when applied in late June and late July. At 11.2 kg/ha it was most effective in July and slightly less so in August. Dieback in this species occurs early in the autumn and may account for the loss of susceptibility in September which was not found in the other species.

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NOTES

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TESTING VARIOUS HERBICIDES, INCLUDING DIPHENAMID AND PROPHAM, FOR WEED CONTROL IN SEEDBEDS OF SITKA SPRUCE (PICEA SITCHENSIS [BONG.] CARR.)

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Summary The results of experiments from 1971 to 1973 (inclusive), in which 17 herbicides were tested on seedbeds of Sitka spruce (Picea sitchensis [Bong.] Carr.), are described. The experiments concentrated mainly on crop tolerance aspects.

Propham (pre-sowing); desmetryne and prometryne (pre-emergence); pentanochlor, propachlor and lenacil (3 months after emergence); and diphenamid and chlorthal-dimethyl (pre- and post-emergence); all caused negligible crop damage. However, observations on weed control showed that only propham and diphenamid gave useful control of Poa annua L., the most common and widespread weed in British nurseries. Results with diphenamid were particularly promising.

Resume On présente les résultats d'expériences effectuées entre 1971 et 1973 et au cours desquelles les effets de 17 herbicides sur les semis de l'épicéa de Sitka (Picea sitchensis [Bong.] Carr.) fut evalués. Les expériences portèrent surtout sur les aspects de la résistance des plantules.

Parmis les 17 herbicides, le propham (pré-semis), le desmetryne et le prometryne (pre-levée), le pentanochlor, le propachlor et le lenacil (3 mois après la levée), le diphenamid et le chlorthal-dimethyl (pré- et post-levée) ne produisèrent que des dommages minimes sur les plantules. Des observations sur les contrôle des mauvaises herbes demonstrèrent que seulement le propham et le diphenamid furent utiles dans les cas du Poa annua L., lequel est le plus répandu dans les pépinières britanniques. Les résultats concernant le diphenamid furent particulièrement encourageants.

INTRODUCTION

No really effective herbicide has been developed for controlling weeds in conifer seedbeds in Britain, although 42 herbicides have been tested by the Research and Development Division of the Forestry Commission between 1948 and 1968 (see Appendix).

At present weed control is achieved by using paraquat or vapourising oil as pre-emergence contact herbicides, white spirit as a post-emergence contact herbicide and a substantial amount of hand-weeding. Hand-weeding, often costing more than £200/ha, is made necessary because crops will not tolerate applications of white spirit until 4 or 6 weeks after germination, in which time the weeds are often too well established for white spirit to give good control.

This paper describes the results up to the end of 1973 of a screening project which commenced in 1971.

METHODS AND MATERIALS

Objective: In previous experiments damage to the crop has often been the reason for discontinuing the development of a herbicide. In these experiments, therefore, assessments of crop reaction to the application of a herbicide formed the main basis for judging the prospects of any compound. Assessments on weed control were secondary, especially in the first two years.

Sites: The experiments were carried out at the following nurseries:-

Headley Nursery, Hampshire (National Grid Reference SU/807 383): 1971 to 73.
Wareham Nursery, Dorset (National Grid Reference SY/880 925) : 1971 to 73.
Bush Nursery, Midlothian (National Grid Reference NT/247 641): 1973 only.

The soil at Headley Nursery is an organic fine to loamy sand, with a pH of 4.4 to 5.0 (in water) and an organic carbon content of about 2.0 to 2.5%. Wareham Nursery soil is a sand to loamy sand, with a pH of about 4.5 (in water) and an organic carbon content of between 2.0 and 4.0%. Bush Nursery soil is a fine sandy loam, with a pH of about 5.8 (in water) and an organic carbon content of about 3.0%. All sites have an average annual rainfall of between 750 and 900 mm.

Selection of Herbicides: All herbicides listed in the 5th Edition, Volume I, Weed Control Handbook (Blackwell) were considered, and the following 17 herbicides selected:-

(1) propham, (2) E.P.T.C., (3) pyrazone, (4) chlorpropham, (5) chlorbufan, (6) asulam, (7) propachlor, (8) alachlor, (9) monolinuron, (10) linuron, (11) lenacil, (12) cycluron, (13) chlorthal-dimethyl, (14) diphenamid, (15) turbuthiolazine, (16) desmetryne, (17) pentanochlor.

Chlorbufan and cycluron could only be obtained in mixture. A further herbicide, prometryne, was included in 1973 because of a promising report from Germany (Schmidt, 1971).

Method of Application: All herbicides were diluted or suspended in water, and the spray solution applied to the surface of 1.0 m^2 plots at 50 ml/m^2 using a small hand sprayer (Oxford Precision Sprayer at Headley and Wareham).

Propham and E.P.T.C. were applied one or two days before sowing, and thoroughly forked into the top 5 to 10 cm immediately after application. Pentanochlor was applied 14 or 21 days after crop emergence*, 42 days after emergence and about 3 months after emergence. All other herbicides were applied both before emergence (14 days after sowing) and after emergence, although not always at all the three post-emergence times mentioned above (see Tables 1, 2 and 3).

*(In these experiments, the date of crop emergence was taken to be the date on which seedlings were first observed on the plots)

In 1971 all herbicides except asulam and chlorthal-dimethyl were applied only at a single dose, that thought to be the lowest useful one. Asulam and chlorthal-dimethyl were also applied at a much higher dose. In 1972 all herbicides were applied at the lowest useful dose and at a dose about half way between the lowest and the highest doses normally recommended for each herbicide (see Fryer, and Makepeace, 1972) . In 1973, all herbicides were applied at the lowest, medium and highest doses. See Tables 1, 2 and 3 for actual doses used.

Each herbicide was not tested every year. Generally, as soon as it was clear that a particular application of a herbicide had damaged the crop this particular treatment was omitted as unsuccessful, unless there were special reasons for retesting this treatment.

<u>The Crop</u>: Seed of Queen Charlotte Isles provenance of Sitka spruce (<u>Picea sitchensis</u> /Bong./(Carr.) was sown in mid-March at Headley and Wareham Nurseries every year, and in early April at Bush Nursery in 1973. Seed was broadcast at 1300 viable seed per m^2. Generally accepted methods of culture were used throughout (see Aldhous, 1972).

<u>Experimental Design</u>: The test of each herbicide was treated as a separate experiment. A control plot, which received no application of the herbicide being tested, was provided for each. Control plots and treated plots were hand-weeded as necessary.

All the treatments for a herbicide were laid out as randomised blocks. In 1971, treatments testing asulam and chlorthal-dimethyl, considered at that time the most promising herbicides, were replicated twice, but treatments testing other herbicides were not replicated. In 1972 and 1973 the treatments of all herbicides were replicated twice, except those of propham in 1973, which were replicated four times.

Plot size was 1.0 x 1.0 m, laid out on the middle of 1.2 m wide seedbeds, with 0.5 m between beds and a minimum of 0.2 m buffer between plots on the same bed.

<u>Assessments</u>: The numbers of seedlings on each plot was counted on either three or four occasions in the first month after germination, then in July (mid-season), and at the end-of-season (late September to November). The heights of seedlings were measured at the end-of-season only and a mean plot height calculated. Both numbers per m^2 and mean height were calculated from a systematic sample assessment, 25% of each plot being assessed for numbers, and 15% for height. Observations on crop health were made regularly throughout the season, and crops scored for symptoms if necessary.

In 1971 and 1972, observations were also made on weed control, but the results of these observations and scores were unsatisfactory because of the erratic distribution of weeds on the plots. In 1973, <u>Poa annua</u> was sown at 4 points on each plot, except plots to be sprayed in July, to give a definite weed population for assessment of herbicidal effects (at Headley and Wareham Nurseries only).

RESULTS

<u>Crop Tolerance</u>

For the 1971 trials, only the data from tests of herbicides which were subsequently rejected is presented, and for 1972 and 1973 trials the results are presented as statistical comparisons indicating significant differences at the

5% level or more. As the end-of-season assessments of numbers and mean height provide the most accurate indication of crop performance, only these are used in this paper.

1971 Experiments

Table 1 gives the results of assessments on end-of-season numbers per m^2 and mean height, expressed as a percentage of the control plot, for herbicides which were totally rejected or for which certain application times were rejected after the 1971 experiments.

Herbicide treatments were generally not tested in subsequent years if either the end-of-season numbers or mean height had been reduced by 15% or more at either nursery, particularly if there were associated damage symptoms. However, pre-emergence treatments of monolinuron were retained for testing for a further year in spite of reductions in end-of-season numbers of this order because of its expected effectiveness against forest nursery weeds. Post-emergence applications of turbuthiolazine and asulam at 3 months after first emergence, caused little reduction in numbers or height, but were rejected. Asulam was rejected because the higher dose tested in this experiment (4 kg/ha) caused considerable reductions in end-of-season numbers and mean height. Turbuthiolazine applications at 3 months after first emergence were considered to be of insufficient interest to warrant further testing although the more damaging pre-emergence application was retained. Linuron and monolinuron post-emergence treatments were excluded in the following year but these were re-introduced in 1973 for re-testing.

Propham at 1.0 kg/ha (pre-sowing), propachlor at 2.0 kg/ha (pre- and post-emergence), lenacil at 0.5 kg/ha (pre- and post-emergence), diphenamid at 3.0 kg/ha (pre- and post-emergence), chlorthal-dimethyl at 4 and 16 kg/ha (pre- and post-emergence) and pentanachlor at 1.0 kg/ha (post-emergence) were retained for retesting in 1972, in addition to those treatments indicated in Table 1, because reductions in end-of-season numbers and mean height were negligible or insufficient to justify rejection.

1972 Experiments

Table 2 gives the results of statistical comparisons between treatments of end-of-season numbers per m^2 and mean height.

With herbicides applied at only one date (pre-sowing or pre-emergence), only propham and desmetryne caused no significant reductions in either numbers or height. With other herbicides, the higher of the two doses caused a significant reduction in either numbers or height when compared with the control, and sometimes even the lowest doses caused significant reductions.

With herbicides applied at several dates, only diphenamid caused no significant reductions in either numbers or height in all comparisons, although chlorthal-dimethyl only caused significant reductions in height when applied pre-emergence and at 21 days after emergence when compared with applications at 3 months after first emergence. In the other three herbicides, the significant differences in the control versus all treated comparisons conceal differences within herbicide treatments.

With pentanochlor, applications at 21 or 42 days after emergence produced significantly smaller seedlings than applications at 3 months after emergence at Wareham, and although there was a significant difference between the two doses even the lower dose reduced height at these dates. Also the higher of the two doses

Table 1

Number and mean height of Sitka spruce seedlings in each herbicide treatment, expressed as % of control plot, at Autumn 1971

(for herbicides with rejected treatment only)

Herbicide	Dose (kg a.i./ha)	(1) Nursery	Date of application: Pre-sowing or emergence		14 days after emergence		42 days after emergence		About 3 months after emergence	
			no.	ht.	no.	ht.	no.	ht.	no.	ht.
E.P.T.C.	2.0	H	88	76	-	-	-	-	-	-
		W	74	74	-	-	-	-	-	-
pyrazone	1.0	H	107	87	124	82	-	-	109	88
		W	90	85	87	65	-	-	94	69
chlorpropham (2)	1.0	H	128	99	92	28	-	-	130	103
		W	92	101	70	22	-	-	96	78
alachlor	2.0	H	73	56	96	123	-	-	96	130
		W	77	90	87	76	-	-	94	78
linuron (2)	0.5	H	89	101	74	95	-	-	83	101
		W	108	96	9	54	-	-	80	64
monolinuron (2)	0.5	H	89	89	56	60	-	-	102	99
		W	102	76	44	49	-	-	111	70
cycluron + chlorbufan	1.0	H	119	88	95	28	-	-	100	65
		W	93	86	66	33	-	-	92	77
turbuthiolazine (2)	0.5	H	89	77	95	104	-	-	120	99
		W	104	107	88	64	-	-	103	92
desmetryne (2)	0.25	H	111	94	98	92	-	-	89	73
		W	107	121	64	76	-	-	104	122
asulam	1.0	H	96	68	99	74	95	71	89	95
		W	94	73	95	90	87	68	99	103

Notes:- (1) H = Headley Nursery
W = Wareham Nursery

(2) Pre-emergence applications retained for retesting in 1972.

(3) 99% confidence limit calculated from all control plots only and expressed as a % of the mean of all control plots:

end of season number = ± 5.9% (H) ± 6.9% (W)
end of season height = ± 9.2% (H) ± 8.6% (W)

Table 2

Results of statistical comparisons on 1972 experiments

Herbicide	Doses of application (kg a.i./ha)	Dates of application	Nursery	Statistical Comparisons: (a) between treatment or (b) control versus all treated – no.	ht.	Within herbicide treatments: within doses – no.	ht.	within dates – no.	ht.	doses x dates – no.	ht.
propham	1.0, 2.0	PS only	H	(a) –	–	not tested					
			W	–	–						
linuron	0.5, 1.0	PR only	H	(a) –	–						
			W	**	–						
monolinuron	0.5, 1.0	PR only	H	(a) –	–						
			W	*	–						
chlorpropham	1.0, 2.0	PR only	H	(a) *	–						
			W	*	*						
desmetryne	0.25, 0.50	PR only	H	(a) –	–						
			W	–	–						
turbuthiolazine	0.50, 1.0	PR only	H	(a) –	–						
			W	*	–						
cycluron + chlorbufon	1.0, 2.0	PR only	H	(a) **	–						
			W	–	–						
pentanochlor	1.0, 2.0	PO1, PO2, PO3	H	(b) **	–	*	–	–	–	–	–
			W	–	*	*	**	–	*	–	–
lenacil	0.5, 1.0	PR, PO1, PO3	H	(b) –	–	*	–	***	–	–	–
			W	*	–	**	–	*	–	–	–
propachlor	2.0, 4.0	PR, PO1, PO3	H	(b) –	*	–	*	*	**	–	–
			W	**	**	*	*	***	**	–	–
chlorthal-dimethyl	4.0, 16.0	PR, PO1, PO3	H	(b) –	–	–	–	–	–	–	–
			W	–	–	–	–	–	*	–	–
diphenamid	3.0, 4.0	PR, PO1, PO3	H	(b) –	–	–	–	–	–	–	–
			W	–	–	–	–	–	–	–	–

Notes: Dates of Application – PS = pre-sowing; PR = pre-emergence (14 days after sowing)

PO1 = post-emergence, 21 days after emergence

PO2 = " " , 42 days after emergence

PO3 = " " , 3 months after emergence

Statistical Comparisons – – = no significance; * = differences significant at 5% level

** = differences significant at 1% level

*** = differences significant at 0.1% level produced significantly less seedlings than the lower dose at both Headley and Wareham, this difference being mainly due to the first two post-emergence applications. At both nurseries, applications at 3 months after emergence caused only slight (and non-significant at 5% level) reductions in crop numbers or height.

With lenacil, applications before emergence and only 21 days after emergence produced significantly less seedlings than applications 3 months after emergence at both nurseries. Again, the higher dose produced significantly less seedlings than the lower dose. Applications of either dose 3 months after first emergence caused only slight and (non-significant at 5% level) reductions in numbers. There were no significant effects on height.

With propachlor, significant differences "within doses" and "within dates" were caused mainly by severe reductions in both seedling numbers and height when the herbicide was applied before crop emergence. However, at the higher dose, crop height was also reduced (but not significantly at 5% level) by post emergence applications, particularly those 21 days after emergence.

Generally, then, with pentanochlor, lenacil and propachlor, applications at either dose caused little or no significant reductions in height or numbers when applied 3 months after first emergence. Applied at the earlier dates they caused either seedling losses or reductions in crop height.

1973 Experiments

Table 3 gives the results of statistical comparison between treatments of end-of-season numbers per m^2 and mean height.

Propham and diphenamid again caused no significant reductions in numbers or height at any dose or, with diphenamid, at any date of application. Chlorthal-dimethyl applications at 21 or 42 days after emergence significantly reduced crop height when compared with other pre-emergence or later post-emergence applications at Wareham Nursery only, but this reduction was only small (at 5% level).

Prometryne caused little reduction in seedling numbers or height when applied before crop emergence, but application at 21 days and sometimes 42 days after emergence (at Wareham) significantly reduced seedling numbers and sometimes height at the 1.0 or 0.1% level. At Wareham these reductions were mainly due to the highest dose. Applications 3 months after first emergence caused no significant reductions.

Desmetryne also caused no reductions in seedling numbers or height when applied pre-emergence, but applications at 21 and 42 days after crop emergence caused highly significant reductions (at 1.0 or 0.1% level) in both numbers and height at both Alice Holt and Wareham. Applications three months after crop emergence caused only small, non-significant reductions (5% level) in numbers and height. The higher doses caused a significantly greater reduction in numbers than the lower, but even the lowest doses caused unacceptable reductions in numbers and height at the first two post-emergence application dates.

Linuron and monolinuron, applied post-emergence only, caused severe crop losses and height reductions (amongst the remaining few) at all dates and doses of application.

Weed Control

Observations on weed control in 1971 and 1972 produced no clear results, probably because either the distribution of weeds throughout the small plots was

Table 3

Results of statistical comparisons on 1973 experiments

Herbicide	Doses of application (kg a.i/ha)	Dates of application	Nursery	Statistical Comparisons: (a) between treatments or (b) control versus all treated		Within herbicide treatments: within doses		within dates		doses x dates	
				no.	ht.	no.	ht.	no.	ht.	no.	ht.
propham	1.0, 2.0 3.0	P3 only	Headley	(a) -	-	-	-	not tested		not tested	
			Wareham	-	-	-	-	"	"	"	"
prometryne	0.5, 1.0 1.5	PR, PO1, PO2, PO3	Headley	(b) -	-	-	-	***	-	-	-
			Wareham	-	-	-	-	**	**	*	-
desmetryne	0.25, 0.50, 0.75	PR, PO1, PO2, PO3	Headley	(b) ***	-	***	-	***	*	*	-
			Wareham	-	-	*	-	***	***	-	-
			Bush	-	-	-	-	-	-	-	-
chlorthal-dimethyl	4.0, 8.0, 16.0	PR, PO1, PO2, PO3	Headley	(b) -	-	-	-	-	-	-	-
			Wareham	-	-	-	-	-	*	-	-
			Bush	-	-	-	-	-	-	-	-
diphenamid	3.0, 4.5, 6.0	PR, PO1, PO2, PO3	Headley	(b) -	-	-	-	-	-	-	-
			Wareham	-	-	-	-	-	-	-	-
			Bush	-	-	-	-	-	-	-	-
linuron	0.5, 1.0, 1.5	PO1, PO2, PO3	Headley	(b) ***	***	**	***	**	**	*	*
			Wareham	***	***	**	-	***	**	-	-
monolinuron	0.5, 1.0 1.5	PO1, PO2, PO3	Headley	(b) ***	***	***	**	***	***	**	-
			Wareham	***	**	***	-	***	-	-	-

Notes: See Table 2

too erratic or because fairly low doses of each herbicide were being tested (especially in 1971). In 1973, sowing Poa annua L. into plots at Headley and Wareham nurseries provided a reliable weed source on which the effect of all herbicide applications (except those three months after crop emergence) could be assessed.

Surprisingly, even the highest doses of prometryne, desmetryne, and chlorthal-dimethyl had little effect on the development of Poa annua, although a slight check in its development was caused by prometryne applied before crop emergence at Wareham and 21 days after crop emergence at Headley. Linuron and monolinuron gave some useful control at both Headley and Wareham nurseries, but the Poa annua recovered by June (in any case crop damage was too severe to consider these herbicides seriously). Propham provided useful check on the development of Poa annua for up to about 8 weeks after crop emergence at the highest dose (3.0 kg/ha).

By far the most promising herbicide was diphenamid, all doses of which applied before crop emergence, provided excellent control for most of the growing season. By July/early August, a few weeds were beginning to invade these plots, indicating its effects cannot be expected to persist all season. Post-emergence (of weed) applications of diphenamid had little effect on Poa annua.

DISCUSSION

Of the 17 herbicides tested in these experiments, most applied at four times with respect to crop emergence, only the following herbicide treatments caused negligible crop damage:-

Propham (pre-sowing + incorporation); desmetryne and prometryne (pre-emergence); pentanochlor, lenacil and propachlor (3 months after crop emergence); diphenamid and chlorthal-dimethyl (pre-emergence and at all times after crop emergence).

However, preliminary indications on the weed control provided by these herbicides suggest that only propham and diphenamid will produce satisfactory control in UK forest nurseries. Diphenamid gave particularly promising results in this respect, and it is interesting to note that this particular herbicide is also giving promising results elsewhere (Dill & Carter, 1972; Van Dorsser, 1970).

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Appendix

Herbicides tested by the Forestry Commission Research and Development Division from 194[illegible] to 1970 for controlling weeds on conifer seedbeds

Name	Reference [Report on Forest Research for year ending March - For.Commn., Lond.(-)].
D.N.O.C.	1950 (1951), 1951 (1952).
ethyl phenyl carbamate	1949 (1950).
m-chloro isopropyl-N-phenyl carbamate (C.I.P.C.)	1956 (1957), 1958 (1959), 1959 (1960).
iso-propyl phenyl carbamate(I.P.C.)	1952 (1953), 1955 (1956).
2-chloroallyl-diethyl-dithio carbamate (C.D.E.C.)	1956 (1957), 1957 (1957), 1958 (1959).
MCPA	1949 (1950), 1950 (1951).
2,4-DES-sodium	1953 (1954), 1954 (1955), 1955 (1956).
MCPB	1956 (1957).
2,4-DB	1956 (1957).
white spirits) vapourising oils)	(1949 (1950), 1950 (1951), 1951 (1952), 1952 (1953), (1953 (1954), 1954 (1955), 1955 (1956), 1956 (1957), (1958 (1959).
high aromatic oils (?)	1951 (1952), 1955 (1956).
tar acids	1959 (1960).
P.C.P.	1951 (1952), 1955 (1956), 1956 (1957).
dilute sulphuric acid	1952 (1953).
allyl alcohol	1952 (1953), 1953 (1954), 1954 (1955), 1957 (1957), 1958 (1959).
sodium chlorate	1952 (1953).
undecylenic acid	1953 (1954), 1955 (1956).
ferrous sulphate	1955 (1956).
3,P-chloro-1, 1 dimethylurea(CMU)	1956 (1957).
T.C.A.	1956 (1957).
monuron	1958 (1959), 1959 (1960).
cycluron + chlorbufen ("Alipur")	1962 (1963).
alpha-chloro-N,N-diallyl acetamide (C.D.A.A.)	1956 (1957), 1957 (1957), 1958 (1959).
dalapon	1958 (1959).
S. 1112 (Shell)	1957 (1957).
S. 776 (Shell)	1957 (1957).
W.L. 1705 (Shell)	1958 (1959).
S.D. 11381 (Shell)	1968 (1968).
dichlobenil	1961 (1962), 1962 (1963), 1963 (1964).
chloramben (amben)	1962 (1963), 1963 (1964).
simazine	1960 (1961), 1962 (1963).
paraquat	1963 (1964), 1964 (1965), 1965 (1966),1966 (1967).
neburon	1963 (1964), 1964 (1965), 1965 (1966).
diuron	1963 (1964).
linuron	1964 (1965).
pyrazone (P.C.A.)	1964 (1965).
pentanochlor	1964 (1965).
propazine	1968 (1968).
naptalam (N.P.A.)	1959 (1960).
endothal	1960 (1961).
dazomet	1969 (1969), 1971 (1971).

THE CONTROL OF GRASSES AND BROADLEAVED WEEDS WITH PROPYZAMIDE IN YOUNG FOREST TREES

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Summary Trials in the UK in 1972-74 with propyzamide at 1.5 and 2.0 lb a.i./ac gave good control of grasses and many broadleaved weeds. Application between mid-November and mid-January resulted in no damage or loss of vigour on 1-5 year planted Norway spruce (*Picea abies*), Sitka spruce (*Picea sitchensis*), Corsican pine (*Pinus nigra* var. *calabrica*), Scots pine (*Pinus sylvestrus*) and Oak (*Quercus sp.*).

INTRODUCTION

Propyzamide is a residual herbicide, which is root absorbed and has no leaf activity. Results in tree, bush and cane fruits reported by Clarke *et al* (1972) record optimum control of perennial weeds from November/December applications. Tolerance in perennial fruit crops led to trials being initiated in 1972 to evaluate the efficacy of propyzamide in the forestry situation and its tolerance in young forest trees.

METHODS AND MATERIALS

In the winter of 1972/73, propyzamide was applied as a 50% wettable powder at 1.68 and 2.24 kg/ha in 860 l/ha. A limited quantity of 2% granular propyzamide was also included in the trials at 2.24 kg/ha and in the winter of 1973/74 4% granular propyzamide was evaluated at 1.68 and 2.24 kg/ha. The standard treatments were atrazine applied as 50% wettable powder at a rate of 2.24 kg/ha and dichlobenil as 7.5% granules at 4.20 kg/ha. The wettable powder was applied by knapsack sprayer fitted with a hollow cone nozzle spraying at a pressure of 3.0 bars. The granular material was applied by hand held shaker.

In 1973/74 there were two main application dates, one in late November and the other in early January. Atrazine and dichlobenil were applied in March.

Details of site location, tree species and age, number of replicates and herbicide application dates are included in Table 1.

Table 1

Tree species and age, replicates and application dates

Site	Species	Age (Yrs) at Spraying	Replicates	Treatment Dates Propyzamide	Dichlobenil	Atrazine
1972/73						
1 Fife	Sitka Spruce	2	3	3.11.72	6.3.73	6.3.73
2 Fife	Sitka Spruce	1	2	3.11.72	6.3.73	6.3.73
3 Norfolk	Corsican Pine	1	2	13.12.72	12.3.73	--
4 Hereford	Corsican Pine	1	2	22.11.72	20.3.73	--
5 Hereford	Oak	1	2	20.12.72	--	20.3.72
1973/74						
6 Aberdeen	Norway Spruce	Various (1-5)	2	15. 1.74	--	--
7 Fife	Sitka Spruce	3	3	5.11.73	15.3.74	--
8 Peebles	Norway Spruce	1	3	28.12.73	--	--
9 Norfolk	Corsican Pine	2	3	10.12.73 8. 1.74	6.3.74	6.3.74
10 Northampton	Corsican Pine	2	3	26.11.73 7. 1.74	5.3.74	--
11 Somerset	Sitka Spruce	1	3	28.11.73 5. 1.74	7.3.74	--

RESULTS

Assessments of weed control were made in the August after treatment in 1973 and 1974. The assessment was based on a 0-10 scale with 10 representing total weed control. A score of 6.5 was the minimum acceptable from the silvacultural viewpoint. Crop vigour was also assessed on a 0-10 scale with 10 representing healthy and 0 complete kill.

Table 2

General Weed Control Assessment - August 73 and 74

Site	Propyzamide Nov/Dec Applic. kg/ha				Propyzamide January Applic. kg/ha				Dichlobenil kg/ha	Atrazine kg/ha
	W.P.		Granular		W.P.		Granular			
	1.68	2.24	1.68	2.24	1.68	2.24	1.68	2.24	4.20	2.24
1972/3										
1 Fife	9	9½	-	9½	-	-	-	-	7½	4
2 Fife	6	5½	-	6	-	-	-	-	8	5
3 Norfolk	7	8	-	-	-	-	-	-	8	-
4 Hereford	8½	8	-	-	-	-	-	-	8	-
5 Hereford	6½	8	-	-	-	-	-	-	-	7
1973/4										
6 Aberdeen	-	-	-	-	8	8½	9	9	-	-
7 Fife	9½	9	8	9	-	-	-	-	7½	-
8 Peebles	-	-	-	-	9½	9	9	9½	-	-
9 Norfolk	8½	9	8½	9	8	8½	9	8½	9	-
10 Northampton	7	7½	7½	7	6½	6½	6	6½	7	-
11 Somerset	7	8	7½	7½	5	6½	6	5	5	-

At sites 1 and 4 propyzamide gave 95% control of Ranunculus repens which was the dominant broadleaved weed in the untreated and dichlobenil treated plots, however, at sites 2 and 10 propyzamide did not adequately control Chamaenerion angustifolium and this accounts for the lower general weed control scores at these sites.

In August control of most of the grasses listed in Table 4 was above 85%. Results with Holcus lanatus were generally good but at site 7 moderate regrowth had occurred at assessment. At site 10 where Calamagrostis epigeijos was the dominant species the young grass was controlled but the matur clumps outgrew the initial effect of both propyzamide and dichlobenil.

With both rates of the w.p. and granular formulations no discolouration, loss of vigour or basal swelling was noted at any of the sites. In Table 3 the lower figures for crop vigour recorded at sites 9 and 11 were a result of damage from Peniophora gigantia and hares respectively.

Table 3

Crop Vigour Assessment - August 73 or 74

Site	Propyzamide kg/ha 1.68	Propyzamide kg/ha 2.24	Dichlobenil kg/ha 4.20	Atrazine kg/ha 2.24
1972/73				
1 Fife	10	10	10	10
2 Fife	10	10	8	10
3 Norfolk	10	10	9½	-
4 Hereford	10	10	10	-
5 Hereford	10	10	-	10
1973/74				
6 Aberdeen	10	10	-	-
7 Fife	10	10	10	-
8 Peebles	10	10	-	-
9 Norfolk	8	8	7	-
10 Northampton	10	10	10	-
11 Somerset	8½	8	6	-

DISCUSSION

From these results it would seem that effective control of most perennial grasses and broadleaved weeds in the situations encountered can be obtained at rates of 1.68 and 2.24 kg/ha, when applied between mid-November and mid-January. No differential response in weed control was detected between the wettable powder and granule formulations when compared at equal rates.

At site 11 in Somerset, January applications of propyzamide did not give as good grass weed control as was experienced in other parts of the UK and further work is necessary to determine if the milder winters of the south west confine application dates to November/December and conversely if the application dates could be extended from October to February in the north of Britain.

Table 4

Control of Grass Species with Propyzamide at 2.24 Kg/ha

(Assessed in August)

Grass Species	Site Number 1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Agropyron repens	8	7½	8	9	8½	10	9½	8½	10	9	9
Agrostis spp.	-	8	7½	10	10	-	8	-	9½	-	10
Anthoxanthum odoratum	10	-	7½	10	9	10	10	10	9½	-	10
Calamagrostis epigeijos	-	-	-	-	-	-	-	-	-	6	-
Dactylis glomerata	-	-	9	9½	9	-	-	-	7½	7½	7
Deschampsia caespitosa	10	10	-	10	10	-	10	10	-	-	-
Deschampsia flexuosa	-	-	10	10	10	-	-	10	10	-	-
Festuca ovina	9	10	-	-	-	9	-	9½	-	-	-
Festuca rubra	9	-	-	-	-	-	9	10	-	-	-
Holcus lanatus	9½	7	9	8	8	-	5	-	8½	8	9
Holcus mollis	-	8	9	9	9	-	-	-	7½	-	-
Poa annua	-	-	10	10	10	10	-	-	10	-	10
Poa pratensis	-	-	-	10	10	-	-	-	-	-	-
Poa trivialis	-	-	10	-	-	-	-	-	9½	-	-

Other tree species not mentioned here which have been reported to be tolerant to propyzamide at 2.0 kg/ha are Douglas fir (Pseudotsuga menzieii (M. Mirbel) Franco) and Western Red Cedar (Thuja plicka (D. Dor)).

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NOTES

AN EVALUATION OF METHODS AND TIMING OF APPLICATION OF CANDIDATE SELECTIVE HERBICIDES IN YOUNG FOREST PLANTATIONS

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Summary Three trials from 1973 and eight trials laid down in 1974 in plantations of Sitka spruce (*Picea sitchensis*), Lodgepole pine (*Pinus contorta*) and Sycamore (*Acer pseudoplatanus*) are reported.

Chlorthiamid granules and atrazine W.P. as standards are compared with W.P. formulation of cyanazine + atrazine, suspension concentrates (S.C.) of cyanazine and cyanazine + atrazine and granules of cyanazine, cyanazine + dalapon and chlorthiamid + dalapon.

Granular materials were applied by means of a Horstine airflow applicator and a prototype gravity applicator from the same company. Liquid applications were applied by means of an Oxford Precision Sprayer and a Hulva very low volume rotary atomiser

At the three sites assessed the high rate of cyanazine + atrazine was the most consistent treatment at all dates, giving acceptable weed control up to 18 months after application and was effective when applied in very low volume (9.8 l/ha). Chlorthiamid + dalapon and chlorthiamid were also effective.

All effective treatments resulted in increases in tree growth.

INTRODUCTION

Weed control is essential during the establishment period of newly planted trees. The cost of hand weeding over the areas of tree plantations that require annual treatment make chemical control methods necessary. Because many plantations are situated in isolated areas, without ready access to water supplies, granular formulations or very low volume applications are to be preferred.

Previous experiments reported by Aldhouse (1964) de Gouville and Allen (1965) Allen (1966), Brown (1968) Allen and Reid (1972) and large scale commercial usage showed that chlorthiamid, as a granule containing 7½% active ingredient, gave an effective control of weeds, when applied at rates of up to 4.2 kg a.i. per treated hectare during the period January-April in Scotland, or January-March in England, Wales and Northern Ireland. In areas where a large weed control programme was being undertaken planting delays frequently made it difficult to apply chlorthiamid within the recommended time period. Work completed in 1973 and reported in January 1974 Allen et al, showed that mixtures of cyanazine with atrazine could safely be applied to young trees outside the time limits required for the application of chlorthiamid. The work described in this paper was designed to confirm the 1973 work with cyanazine + atrazine mixtures; to evaluate other candidate herbicides within and outside the time limits of chlorthiamid and to assess different applicators for both granular and water carried formulations.

METHODS AND MATERIALS

Eight trials at three different sites are reported. At site No.1 there were five trials applied at five different dates. At site No.2 there were two trials applied at two dates and at No.3 there was one trial.

Table 1

Materials sites and date of treatment

Treatment	Rate	Form	Application timing at each site				
			E. March	Late March	April	May	June
Atrazine	4.48	*W.P.		1 2	1 2 3		
Chlorthiamid	4.2	Gran	1	1 2			
Cyanazine/ Atrazine	1.79/1.79	W.P.	1	1 2	1 2 3	1	1
"	2.69/2.69	W.P.					
"	3.58/3.58	W.P.	1	1 2	1 2 3	1	
"	1.79/1.79	+S.C					1
"	2.69/2.69	S.C.				1	1
"	3.58/3.58	S.C.				1	
Chlorthiamid/ Dalapon	1.12/1.5	Gran					1
"	2.24/3.0	Gran		1 2	1 2 3		
"	3.36/4.48	Gran		1 2	1 2 3		
Cyanazine	2.8	S.C.					1
"	4.48	S.C.		1 2	1 2 3	1	
"	2.8	Gran					1
"	3.36	Gran	1				
"	4.48	Gran	1	1 2	1 2 3	1	
"	6.72	Gran	1				
Cyanazine/ Dalapon	1.12/1.5	Gran					1
"	2.24/3.0	Gran				1	1
"	3.36/4.48	Gran			1 2 3	1	1
"	5.04/6.72	Gran				1	
		Site 1	6/3	20/3	10/4	14/5	21/6
		Site 2		22/3	29/4		
		Site 3			27/4		

* W.P. = Wettable Powder
\+ S.C. = Suspension Concentrate

The granular materials were applied in a continuous band of approximately 1 metre in width over the trees by a Horstine Farmery airflow granular applicator. The wettable powders and suspension concentrate formulations were applied by an Oxford Precision sprayer at 620 litre/ha., again over the trees to the same band width. Four randomised blocks were treated in each trial, there was an untreated control in each block. The plot size was 9.1m long containing a single row of trees.

At site No.1, 8 unreplicated observation plots were laid down to assess the merits of different applicators for granules and water carried materials. The plot sizes were 18.3 x 7 metres (four rows of trees). Chlorthiamid was applied by means of the Horstine Farmery airflow granular applicator and a prototype gravity applicator at 4.2 kg a.i./ha as a continuous one metre band over the trees. In addition the gravity applicator was used to apply Chlorthiamid at the same rate as a spot treatment 1 metre x 1 metre over individual trees.

The proto-type granular applicator consists of a hopper mounted on the operators back, with an outlet pipe running from each side of the hopper. Each of the outlet pipes runs through a metering device, situated on either side of the operator, to a spreading nozzle. The two spreading nozzles are mounted on a telescopic bar held in front of the operator; at the setting used each nozzle gave a spread of approximately 0.5m.

Wettable powder and suspension concentrates of cyanazine and atrazine were applied over the trees by Hulva rotary atomiser as a band and overall application at 3.58 + 3.58 on a 1 metre band and 2.69 + 2.69/kg/ha overall. The Ulva rotary atomiser was used to apply cyanazine and atrazine as a wettable powder at 2.69/2.69 kg/ha. At site No.3, 1 plot in each block was treated with the gravity granular applicator applying 4.2 kg a.i./ha of chlorthiamid 7½% granules as a 1 metre band over the trees. An area of approximately 200 sq. metres comprising 8 rows of trees was treated by the Hulva rotary atomiser with cyanazine + atrazine suspension concentrate formulation at 2.69/2.69 kg/ha. In two rows the treatment was a 1 metre band over the trees and in the remaining 6 rows treatment was overall.

Table 2

Details of Crop and Weeds at the three sites:

Site 1	Site 2	Site 3
Location: Perthshire	Perthshire	Durham
Specimen: Sitka Spruce (*Picea sitchensis*)	Sitka Spruce (*Picea sitchensis*)	Lodgepole pine + Sycamore (*Pinus contorta*) (*Acer psendophetanus*)
Main Weeds:		
Agrostis stolonifera	*Festuca rubra*	*Ranunculus repens*
Agrostis gigantea	*Galium verum*	*Trifolium pratense*
Festuca ovina	*Anthoxanthum odoratum*	*Circsium vulgare*
Holcus lanatus	*Poa pratensis*	*Circsium arvense*
Juncus effusus	*Rumex acetosella*	*Chrysanthemum leucanthemum*
Anthoxanthum odoratum		*Vicia spp*
Galium verum		*Anthoxanthum odoratum*
Achillea millefolium		*Dactylis glomerata*
Medicago lupulina		*Taraxacum officinale*
Vicia spp		*Lolium perenne*

RESULTS

Weed control was assessed at each site. A figure of commercial silvicultural acceptability was arrived at and is expressed as 30% weed cover remaining. At the end of the growing season, at each site, the weed control was assessed by up to 4 assessors the figures shown are the mean scores. At the time of application and at the end of the season the trees were counted in each plot and were classified as healthy, damaged or dead. As there was no tree damage or death resulting from any treatment in any of the trials, these figures are not shown.

Table 3

Treatment

Site 1

Mean weed cover remaining 1974 annual increment ( ) cms (Site 1)

Tree species and age: Sitka spruce planted 1973

			Application Dates				
Compound	Form	Kg/ha	Mar.6th	Mar.20th	Apr.4th	May 14th	June 21st
Atrazine	W.P.	4.48		11.4(22)	20.8(16)	17.3(23)	
Chlorthiamid	G	4.2	13.5(22)	11.8(20)	13.8(19)		
Cyanazine + Atrazine	W.P.	1.79/1.79					29.5(24)
"	W.P.	2.69/2.69	9.3(19)	8.4(21)	32.8(16)	18.3(24)	17.3(20)
"	W.P.	3.58/3.58	7.4(23)	8.8(26)	15.4(22)	9.4(25)	
"	S.C.	1.79/1.79					26.5(20)
"	S.C.	2.69/2.69				20.3(24)	13.0(24)
"	S.C.	3.58/3.58				11.8(23)	
Chlorthiamid + Dalapon	G	1.12/1.5					56.5(20)
"	G	2.24/3.0		8.5(33)	56.5(14)		
"	G	3.36/4.48		5.5(23)	16.3(18)		
Cyanazine	S.C.	2.8					44.0(26)
"	S.C.	4.48		21.9(29)	32.6(19)	24.1(20)	
"	G	2.8					53.8(17)
"	G	3.36	42.0(22)				
"	G	4.48	37.0(20)	49.3(21)	47.0(21)	52.8(19)	
"	G	6.72	15.4(18)				
Cyanazine + Dalapon	G	1.12/1.5					60.0(26)
"	G	2.24/3.0				42.8(20)	56.5(24)
"	G	3.36/4.48			12.4(15)	19.6(19)	42.3(22)
"	G	5.04/6.72				15.9(20)	
Untreated control			79.5(13)	82.1(19)	84.4(17)	59.5(18)	55.0(23)

Cyanazine/atrazine wettable powder at 3.58/3.58 kg/ha performed well at each date and was the most consistent treatment. The lower rate of 2.69/2.69 kg a.i./ha only failed in April. The cyanazine/atrazine wettable powder formulation and the suspension concentrate formulation were directly comparable. Chlorthiamid + dalapon gave an acceptable degree of weed control at the higher rate of 3.36/4.48, but at the lower rate of 2.24/3.0 failed to give acceptable control when applied in April.

Cyanazine S.C. was markedly superior to equivalent rates of cyanazine granules which failed to give acceptable weed control. Cyanazine/dalapon granules at 3.36/4.48 and 5.04/6.72 kg a.i./ha were acceptable following the April and May application but the lower rate failed in the June application. Of the two standards used Chlorthiamid 7½% granules at 4.2 kg a.i./ha was more consistent than 4.48 kg a.i./ha of atrazine wettable powder.

The annual increments of the trees are shown in cms. There are very few cases where the increments in the treated plots are not considerably greater than in the control plots. Treatments applied in April are exceptional probably because of the excessively dry weather that month.

Table 4

Mean % weed cover remaining at end of season

Treatment			Application date		
			Site 2		Site 3
Compound	Form	Kg/ha	March 22nd	April 29th	April 27th
Atrazine	W.P.	4.48	30.3	59.8	5.3
Chlorthiamid	G	4.20	36.0	42.5	10.6
Cyanazine/atrazine	W.P.	2.69/2.69	33.0	59.5	5.0
" "	W.P.	3.58/3.58	15.8	35.5	3.5
Chlorthiamid/dalapon	G	2.24/3.0	25.6	61.3	24.1
" "	G	3.36/4.48	24.4	30.0	5.5
" /cyanazine	G	2.8/2.8	53.6	55.0	20.8
" "	G	3.36/3.36	50.8	41.5	11.3
Cyanazine	S.C.	4.48	75.0	70.0	12.0
"	G	4.48	64.0	81.3	44.1
Cyanazine/dalapon	G	3.36/4.48		43.8	28.9
Untreated control			85.0	76.3	75.8

At site No.2 the area had been felled by heavy snow and the remains of the fallen trees and brush placed in swathes by bulldozer. The new re-planted trees in the trial were in two rows between each swathe of fallen trees. The young trees were in many cases growing underneath overhanging parts of the fallen trees and application of herbicides presented a problem. The predominant grass was *Festuca rubra* which proved to be moderately resistant to some of the treatments. The difficulty of application and the presence of this weed may account for the general poor degree of weed control. In the March application only cyanazine/atrazine at 3.58/3.58 kg/ha and the two rates of chlorthiamid/dalapon were acceptable. The addition of dalapon to chlorthiamid greatly improved the control of *Festuca rubra*. In the April application the high rate of chlorthiamid/dalapon 3.36/4.48 kg a.i./ha was the only treatment to give acceptable weed control. Once again as in site No.1 the April treatments were less effective than their equivalents in March.

Site No.3 consisted of a shelter belt of trees planted on reclaimed open cast mine workings by the National Coal Board and was atypical of normal forest sites. The site has a high degree of fertility and was sown with cocksfoot (*Dactylis glomerata*), perennial ryegrass (*Lolium perenne*) and red clover (*Trifolium pratense*) prior to the planting of the trees. All the treatments were extremely effective with the exception of cyanazine granules which at 4.48 kg a.i./ha failed to give acceptable control. The best treatments were cyanazine + atrazine at 2.69/2.69 and 3.58/3.58 kg a.i./ha which reduced the weed cover from 75% to 5% and 3.5% respectively. The mixed granule of chlorthiamid/dalapon gave a better control of red clover, than chlorthiamid.

Comparison of Methods of Application

Table 5
% Weed Cover Remaining at end of Season at each site ( )

Treatment			Method of Application					
Compound	Form	Kg a.i./ha	A	B	C	D	E	F
Chlorthiamid	G	4.20	19(1)	28(1) 22.5(2)	6(1)			
Cyanazine/atrazine	W.P.	2.69/2.69				22.5(1)		
"	W.P.	2.69/2.69					15(1)	
"	W.P.	3.58/3.58					7.5(1)	18(1)
"	S.C.	3.58/3.58						17(1)
"	[illegible]	[illegible]					[illegible]	[illegible]

A=Horstine Airflow (Band) B=Horstine gravity (Band) C=Horstine gravity (spot)

D=Hulva (overall) E=Hulva (overall) F=Hulva (Band)

All the treatments were acceptable. Application by the motorised airflow applicator resulted in better weed control than the gravity machine, but the gravity machine was highly effective when used to apply a spot treatment. The cyanazine + atrazine treatments were both effective when applied by means of the Hulva machine, either as a band or overall. There was no difference between equal rates of the wettable powder and the suspension concentrate formulation.

Cyanazine + atrazine, at both rates used, gave excellent control of Anthoxanthum odoratum (sweet vernal grass) at Site No.1.

Residual effects of treatments in subsequent year:-

A site treated at monthly intervals in 1973 and reported 1974, Allen M.C. *et al* (1974), was assessed again in Autumn 1974 for weed control. The Annual growth increments for 1974 were also measured and are shown in cms in table 6.

Table 6
% Weed Cover remaining and 1974 growth increments cms. ( )

1973 and 1974 assessments of application completed in 1973 Perthshire Sitka spruce

Treatment	rate kg/ha	March '73	March '74	inc	April '73	April '74	inc	May '73	May '74	inc	Mean '74 All Months
Atrazine W.P.	4.48	24	47	(22)	15	33	(17)	15	36	(23)	39
Atrazine granules	4.48	30	27	(28)	27	32	(22)	51	33	(26)	30
Chlorthiamid	3.36	21	49	(22)	14	35	(21)	-			42
Chlorthiamid	4.20	22	54	(24)	14	32	(18)	-			43
Cynazine/atrazine W.P.	2.39/2.39	19	36	(24)	10	32	(20)	17	41	(19)	36
" " "	3.58/3.58	11	27	(22)	11	32	(26)	10	27	(20)	27
" " "	4.48/4.48	13	20	(22)	9	22	(25)	7	15	(22)	19
Untreated control		77	76	(20)	83	76	(17)	65	68	(22)	73

Weed control from atrazine W.P. deteriorated over the period Spring 1973 - Autumn 1974 and was not acceptable in any month. Atrazine granules at the same rate improved in March and May, probably due to the slower breakdown of the granules. Clorthiamid, at both rates failed to give an acceptable degree of weed control in the year after application. Cyanazine + atrazine at the two higher rates gave acceptable weed control at each month of application. With the exception of atrazine granules the level of weed control in 1973 was reduced by approximately 50%.

DISCUSSION

The availability of water remains a problem in the remote areas of afforestation and granular herbicides are to be preferred. However there are time constraints upon the application of granular materials such as chlorthiamid. The planting programme must be completed as soon as possible in the spring and the time limits have often expired before the labour force becomes available for weeding previous year's plantings. The use of cyanazine/atrazine mixtures at 2.69/2.69 or 3.58/3.58 kg a.i./ ha would seem to offer a real alternative for use outside the time limits of chlorthiamid, particularly if a very low volume method of application could be used.

The Ulva very low volume applicator did not give as good results as the Hulva and presented more problems to the operator. It was also more inclined to drift on the exposed sites. It was noticeable at site No.3 that Trifolium pratense was well controlled by the cyanazine/atrazine mixtures and that at site No.1 Anthoxanthum oderatum, which is resistant to chlorthiamid, was well controlled. In chlorthiamid treated areas where Anthoxanthum oderatum is prevalent it tends to rapidly colonise when the competing grasses have been removed. The mixture would therefore seem to be well suited for application as an alternative or 'follow up' treatment to chlorthiamid.

It is of interest to note that without exception treatments applied on April 4th were markedly worse than the same treatments applied on March 6th or March 20th and on occasion on May 14th. This is contrary to normal forestry experience and can be attributed almost entirely to the fact that April 1974 was the driest April in Scotland for some 150 years.

Effect on tree growth

The benefits of removing grass and herbaceous weed competition from young growing trees have for sometime been in doubt. It has never been clear whether or not any benefit in terms of tree growth were to be gained from the removal of competition or if a heavy grass infestation tended to 'draw' the trees upwards and that the only danger was from the smothering effect of grass and dying vegetation falling upon the tree in the autumn. In the trials reported in almost every case an effective degree of weed control has resulted in growth increments greater than those of the control. In Table 1 most of the increments are in excess of 20% of control. In the chlorthiamid/dalapon treatment on March 20th at site 1 the increment is 73% above that of the control. The growth increments shown in Table 4 are again almost all considerably better than the untreated control plot increments. From the trials reported it would appear that the removal of competition does unquestionably have a beneficial effect upon a young trees' growth. The benefits to the trees in the year after application are shown in Table 4. If the results from these trials can be repeated these treatments can be considered to be suitable for the provision of 2 year's weed control from one application.

Acknowledgments

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3-CYCLOHEXYL-6-(DIMETHYLAMINO)-1-METHYL-1,3,5-TRIAZINE-2,4(1H,3H)-DIONE (DPX 3674) - A NEW NON-SELECTIVE HERBICIDE WITH CONTACT AND RESIDUAL PROPERTIES

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Summary 3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione (DPX 3674) has been investigated in trials for the last two seasons. A very wide range of perennial broad-leaved weeds and grasses have been controlled including a number of shrub and tree species. Optimum levels of weed control are achieved when application is made during the period of maximum vegetative growth. The strong contact and residual properties of the chemical can be used most effectively with this treatment pattern. The 1974 trials programme has been designed to establish the optimum rates for controlling different weed species in varying situations.

INTRODUCTION

No common name has yet been established for 3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione. It has a code number of DPX 3674 and the trade name of VELPAR is used for herbicide formulations based on this active ingredient. This chemical was first introduced into Europe by E.I. du Pont de Nemours Inc. for intensive development early in 1973. Initial screening had indicated a high level of contact and residual weed control. The chemical offers a low degree of hazard. It has a moderate acute oral toxicity (active ingredient LD_{50} 1690 mg/kg - male rats) and a low dermal and inhalation toxicity. There is no evidence of cumulative toxicity. Ecological considerations are favourable in view of its low toxicity to birds and fish and relatively short persistence in the soil.

Trials have been carried out in the U.S.A. with DPX 3674 at rates varying from 4.5 to 13.5 kg/ha with both liquid and water soluble formulations. Formulation has not been found critical, although under U.S. conditions the addition of surfactant has improved weed control. A wide spectrum of weeds has been controlled but *Sorghum halepense* and *Campsis radicans* are resistant at up to 13.4 kg/ha. Higher rates have been found necessary in the high rainfall areas.

In Germany in 1973 trials at 3 centres compared 5, 10 and 15 kg/ha following application to a range of weed species with applications made on May 19th or July 26th. At one site by October 17th mosses had largely taken over the plots. All weed species had been controlled apart from *Convolvulus arvensis*, which was present on the 5 and 10 kg/ha plots. In another trial the foliar activity of DPX 3674 was compared to bromacil at 5 and 10 kg/ha and assessed 6 weeks after application, during which period no rainfall was recorded.

Results are given below:-

Product	Rate kg/ha	% Control Grass spp.	Convolvulus arvensis	Galium aparine	Potentilla reptans	Equisetum arvense
Bromacil	10	95	25	50	50	80
Bromacil	15	90	30	70	70	80
DPX 3674	4.5	90	85	80	70	95
DPX 3674	9.0	95	90	85	80	100
DPX 3674	13.5	100	90	95	95	100

Further development work is being carried out in the U.S.A., Germany and elsewhere during 1974 to establish weed species response at various rates, to investigate the susceptibility of DPX 3674 to surface water movement and to assess the possible advantages of adding DPX 3674 to other herbicides. Early trials have indicated that a number of bush and trailing vine species are susceptible.

In the U.K. trials in 1973 were aimed at establishing herbicidal effects from a range of rates. Two replicated and two observation trials were carried out on sites covering a wide spectrum of the more difficult annual, biennial and perennial weeds.

In 1974 an extensive series of replicated and commercially applied trials were initiated to investigate the following factors: rate response to an extensive range of common weed species, effect of timing, length of residual activity and the influence of soil type on efficacy and rate of disappearance.

METHODS AND MATERIALS

U.K. Trials

1973 Two replicated trials, each with three replicates, were carried out with DPX 3674 applied at 4.5, 9.0 and 13.5 kg/ha using a liquid formulation containing 4lb a.i./U.S. gallon.

At Purfleet the site consisted of well established vegetation growing on industrial wasteland, consisting largely of deep alluvial soil. A range of weed species were present including Arrhenatherum elatius, Agrostis stolonifera, Poa pratensis, Cirsium arvense and Heracleum sphondylium with occasional patches of Phragmites communis, Cardaria draba, Rumex crispus and Rubus fruticosus.

At Waltham Abbey the weed spectrum was almost entirely grasses with 90-99% cover on all plots. The principal grasses included Holcus lanatus, Phleum pratense, Dactylis glomerata, Arrhenatherum elatius and some Agropyron repens. Rates applied to the three replicates were 2.2, 4.5 and 9.0 kg/ha.

At the two observation trials the weed spectrum was: Nottingham - Equisetum arvense, Hypericum perforatum, Linaria vulgaris, Artemesia vulgaris, Cardaria draba and Chamaenerion angustifolium. Kent - Galium aparine, Rubus fruticosus, Convolvulus arvensis, Matricaria spp. and a range of annual weeds.

Only 3.14 kg/ha was evaluated in Kent but 2.2, 4.5, 9.0 and 13.5 kg/ha at Nottingham. Application to the Purfleet, Waltham Abbey and Nottingham sites was by pressure knapsack sprayer with 4 nozzle boom fitted with 00 ceramic fan jets at 1.4 bars and applying 1125 l./ha. Plot size was 2.7m x 3.7m but larger at Kent (0.3 ha). At Purfleet and Waltham Abbey the standard product was bromacil applied at similar rates of 4.5, 9.0 and 13.5 kg/ha. A bromacil +2,4-D + 2,4,5-T tank mix 'cocktail' was applied at Kent but no standard was included at Nottingham. Application was made to all trials during the period of active vegetative growth: Purfleet - 22nd and 24th May, Waltham Abbey - 30th May, Nottingham - 7th June, and Kent - 14th June. No additives or surfactants were added to any of the treatments.

1974 6 replicated, 3 observation trials and numerous commercially applied trials were laid down in a wide range of geographical locations from Savernake Forest to Darlington. The basic aim of trials was to investigate the rate response on common and problem weeds, particularly those weeds not controlled by substituted urea, substituted uracil and triazine herbicides. A further objective was to determine how the results of treatments varied with the timing of application and the growth stage at treatment of different weed species. A range of soil types was selected from ash and gravel base with high carbon content to more normal agricultural soils. Rates varied slightly from site to site but covered the range of 1.0 - 12.1 kg/ha applied during the period of active growth from mid-April to early June.

Plot size in the replicated trials was 4.6m x 1.8m with 3 replications and 13.7m x 1.8m in the observation trials. Area covered in the commercial trials varied but was always very much larger. Replicated and observation trial treatments were applied with an Oxford Precision Sprayer or pressure knapsack sprayer with a 5 and 4 nozzle boom equipped with fan jets spraying 450 l./ha at 1.4 - 2.0 bars. Commercial trials were applied with a range of commonly used knapsack and powered sprayers including specially developed train sprayers.

The standard products in all trials were bromacil at 2.0 - 7.2 kg/ha and a mixture of bromacil and diuron (40% + 40%) at 5.4 - 8.1 kg/ha. Where resistant weeds were present no standard products were applied.

RESULTS

1973

Purfleet

One month after treatment the 4.5 kg/ha DPX 3674 plots were exhibiting 90% foliar kill with survival of some Potentilla reptans, Heracleum sphondylium, Cirsium arvense, Cardaria draba, Rubus fruticosus, Agropyron repens and Tussilago farfara. 9 kg/ha gave an increasing effect on these species which were largely killed at 13.5 kg/ha except for Cardaria draba, which showed only partial kill. Phragmites communis was not controlled at any of the rates.

The final assessment was made on 27th September when no further vegetative growth could be expected. Visual differences between the three rates of DPX 3674 were very small but resulted in 2 - 4 times less live vegetation compared to similar rates of bromacil. See Table 1 for end of season live vegetation scores and Table 3 for weed control ratings.

Table 1

Site - Purfleet

% live vegetation on plots 27.9.73.

Date of application: 22nd and 24th May 1973

Product	DPX 3674			Bromacil		
Rate: kg/ha	13.5	9.0	4.5	13.5	9.0	4.5
Total vegetation	15	10	6	43	20	26
Grass spp.	-	-	3	-	-	2
Phragmites communis	10	5	-	15	4	-
Potentilla reptans and Rubus fruticosus	-	2	2	22	7	20
Other broad-leaved weeds	5	3	1	6	9	6

Waltham Abbey

Foliar top-kill improved with increasing rate. One month after treatment weed control was from 50 up to 75% with only broad-leaved species still green. By 27th September all species had been controlled, although even at 9.0 kg/ha Agropyron repens was not completely killed. 2.24 kg/ha DPX 3674 was equivalent to 4.5 kg/ha bromacil but at 9 kg/ha both products were giving equivalent vegetation control.

See Table 2 for end of season live vegetation scores and Table 3 for weed control ratings.

Table 2

Site - Waltham Abbey

% live vegetation on plots 27.9.73.

Date of application: 30th May 1973

Product	DPX 3674			Bromacil	
Rate: kg/ha	9.0	4.5	2.2	9.0	4.5
Total vegetation	7	14	30	8	28
Grass spp.	7(A)	8(A)	18	3	22
Broad-leaved spp.	-	6	12	5	6

(A) largely Agropyron repens

Nottingham and Kent

At the end of August Equisetum arvense control was 30% with 2.2 kg/ha and

4.5 kg/ha, 70% with 9.0 kg/ha and 80% with 13.5 kg/ha. *Hypericum perforatum* was only controlled at the high rate and there was some survival of *Chamaenerion angustifolium* and *Linaria vulgaris* shoots. In a single plot *Polygonum cuspidatum* was completely killed with 13.5 kg/ha. At Kent all species except *Convolvulus arvensis* had been controlled and *Rubus fruticosus* was recovering after leaf kill.

Table 3

Weed Control Results from 1973 Trials

Number of crosses (+) indicating increasing susceptibility of species to chemical at rates given.

R = resistant
? = not found

	DPX 3674 (kg/ha)				Bromacil*
Broad-leaved weeds	2.2	4.5	9.0	13.5	
Aegopodium podograria	++++	++++	++++	++++	MR
Anthriscus sylvestris	?	++++	++++	++++	-
Cardaria draba	R	R	R	+	MR
Chamaenerion ang.	R	++	+++	?	MS
Cirsium arvense	++	+++	++++	++++	MR
Convolvulus arvensis	R	R	R	+	R
Equisetum arvense	R	R	+	++	MR
Galium aparine	++++	++++	++++	++++	-
Glechoma hederacea	R	R	?	?	MS
Heracleum sphondylium	++	++	+++	++++	MR
Hypericum perforatum	R	R	R	+++	MS
Linaria vulgaris	?	R	R	+	MR
Malva spp.	?	++++	++++	++++	-
Plantago spp.	?	++++	++++	++++	S
Polygonum cuspidatum	?	?	?	++++	MR
Potentilla reptans	?	+	++	++	R
Rubus fruticosus	?	++	++++	++++	(R)
Rumex spp.	+++	++++	++++	++++	MR
Senecio jacobea	?	++++	++++	++++	S
Taraxacum officinale	R	R	?	?	MS
Tussilago farfara	R	+	+	++	MS

All grasses appeared to be susceptible between 4.5 and 13.5 kg/ha although *Agropyron repens* exhibited regrowth except at the high rate. *Phragmites communis* was resistant.

*Data obtained from Weed Control Handbook, 6th Edition.

1974

Experience in 1973 indicated that the residual activity of the chemical could further enhance control levels achieved through primary contact action. Consequently preliminary weed control assessments carried out at the 1974 trial sites have not been included in this paper. Final assessments of the weed control achieved on the different sites will be carried out at the end of the growing season in late September and early October and will be reported at the Conference.

Preliminary weed control assessments have confirmed the strong contact action, particularly under high temperature conditions. A high level of grass control has been recorded in all trials regardless of the species, even at low rates. There are indications that rates of 4 kg/ha or more may be required for rhizomatous and tussocky grass species. Control of Equisetum arvense has been disappointing even at 8.1 kg/ha and regrowth of Convolvulus arvensis has been recorded at 8.1 kg/ha. In general 4.0 kg/ha appears to be the rate at which acceptable levels of control are occurring. Heracleum sphondylium control has been 80% at 4.0 kg/ha with similar control of Ranunculus repens, Epilobium spp., Plantago and Urtica dioica. It is too early to assess the effect of soil type and organic matter content on weed control levels.

DISCUSSION

In 1973 trial sites were deliberately chosen for the wide spectrum of more difficult to control annual and perennial weeds. Spraying was carried out during a period of dry and hot weather when growth was very active. Up to 100% foliar top-kill occurred within 4 weeks, indicating strong contact action. The residual properties of the chemical became increasingly evident and by the end of the growing season little regrowth was noted. Most grasses seemed readily controlled, although 13.5 kg/ha was necessary for complete kill of Agropyron repens. Equisetum arvense was 80% controlled at 13.5 kg/ha but it was felt that more appropriate timing could improve control levels. The weed species response needs further confirmation in view of the small amount of data available and the often irregular occurrence of the individual species. Nevertheless these preliminary trials indicated a wide spectrum controlled and a greater degree of foliar activity compared with bromacil on a rate for rate basis.

Preliminary results from 1974 would confirm the broad spectrum of weeds controlled and the high level of top-kill. Our observations would confirm U.S. experience where foliar activity has been noted in 4 days when the mean day temperature is around 20°C but under cooler conditions 7 - 14 days is more normal for top-kill to be noted. Timing appears to be more critical with optimum foliar activity achieved when treating young plants in an actively growing vegetative phase. Once the reproduction stage is reached and the plants are more fibrous, foliar activity is reduced, though final kill may not be affected. End of season assessments are necessary to establish final control. Volume of water does not appear to be critical but higher (more than 450 l./ha) volumes and pressure are likely to improve foliar uptake when foliage is tall and dense.

Final weed control assessments will be carried out at the end of September when the residual activity of the chemical will have become fully apparent.

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FACTORS AFFECTING THE OVERWINTERING OF VOLUNTEER POTATO TUBERS AND THE EMERGENCE OF SPROUTS IN THE SPRING

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Summary It was shown in the first of two experiments that only tubers on or near to the soil surface were killed during the winter 1972-73. Those tubers deeper in the soil (5-20 cm) were unaffected by the adverse weather conditions. In the other experiment ploughing was found to bury tubers deeper in the soil than rigid tine cultivation thus protecting them from the winter weather and increasing survival.

The emergence of the potato sprouts in the spring was influenced by tuber depth, those at 20 cm reaching 80% emergence 10 days after the tubers at shallower depths. However the greater depth of the tubers in the ploughed plots of the second experiment did not delay emergence. The presence of winter wheat and spring barley drilled into the plots, reduced tuber survival and delayed sprout emergence compared with plots where the cereals were absent.

INTRODUCTION

An amelioration of the groundkeeper potato problem would be achieved if the percentage tuber survival over the winter could be reduced. Those tubers on or near to the soil surface are more likely to be frosted and killed during the winter than those deeper in the soil. Thus cultivation techniques that do not bury the tubers in the soil expose more tubers to the adverse winter weather conditions and may reduce tuber survival. The presence of crop cover during the winter may also increase survival as the soil underneath a crop experiences less extreme temperatures than bare ground (Carson, 1961).

Besides affecting tuber survival the depth distribution of tubers in the soil may influence the timing of sprout emergence in the spring. Studies carried out in winter wheat in 1973 showed that sprout emergence started at the end of April and continued into June (Lutman & Elliott, 1973), thus making the timing of post-emergence herbicide treatments very difficult. If all the tubers remained near to the soil surface the emergence period might be shortened, improving the possibilities for post-emergence control.

The first experiment described in this paper investigated the influence of tuber depth on survival over the latter part of the winter 1972-73 and its effect on sprout emergence in the spring. In the second experiment the effects of cultivation techniques on the depth distribution of tubers, on their survival over the winter, and on sprout emergence in the spring was determined. The modification of the effects of these cultivation treatments by the presence or absence of a cereal crop was also investigated.

METHOD AND MATERIALS

Tuber depth experiment

Tubers of the potato varieties King Edward, Pentland Crown, Pentland Dell and Majestic were planted at five depths in the soil; 0, 2.5, 5.0, 10.0 and 20.0 cm below the soil surface. Forty tubers were planted in each plot on 1.2.73 and eight randomised samples of five tubers were taken from each plot at approximately 14 day intervals thereafter. The number of healthy tubers and the number with emerged sprouts in each sample was recorded. The experiment was replicated three times and the results were subjected to analyses of variance.

Cultivation experiment

In a 3 x 3 factorial experiment replicated four times 36 potato tubers (cv. King Edward) were planted approximately 5 cm below the soil surface, 50 cm apart in the centre of each of the 36 plots, at the beginning of November. Immediately after planting the plots were either ploughed to a depth of about 25 cm, or were cultivated with a rigid tine cultivator to the same depth, or were left undisturbed. Winter wheat (cv. Maris Huntsman) was then sown on twelve of the plots. The following spring, barley (cv. Julia) was drilled into twelve more plots, thus leaving twelve plots with no cereal crop.

The emergence of potato sprouts was recorded at intervals from the middle of April to the middle of July, when the cereals were removed and the sprouted tubers were harvested. The number of sprouted tubers per plot was recorded and their depth in the soil was measured.

RESULTS

Tuber depth experiment

Only those tubers on or near to the soil surface were killed during the winter (Table 1).

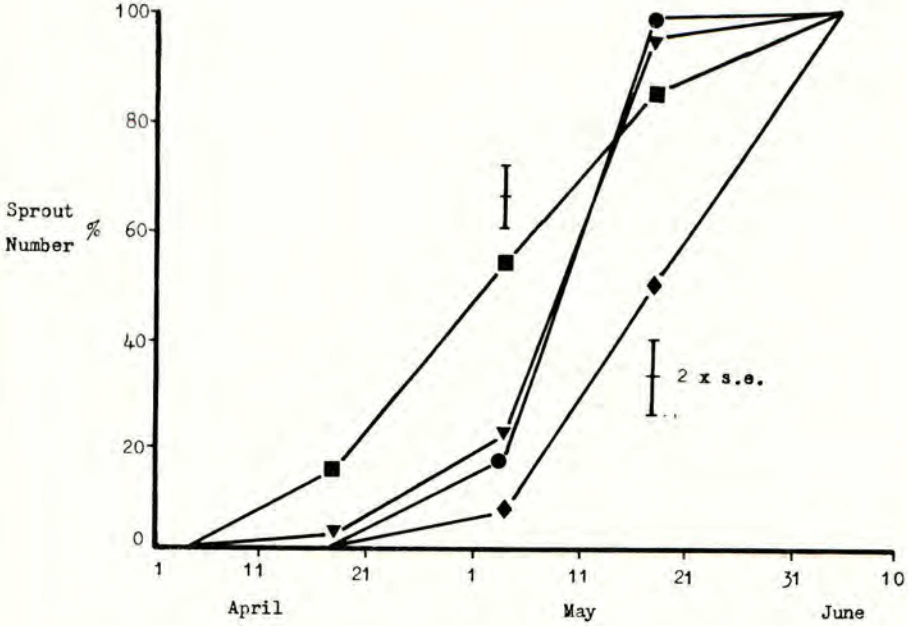
Table 1

The effect of variety and of planting depth on the survival of potato tubers over the latter part of the winter of 1973. Data expressed as a percentage of the number of tubers planted

Variety	Depth of tubers in the soil (cm)				
	0	2.5	5	10	20
King Edward	0	73	100	100	100
Majestic	0	73	93	93	100
Pentland Crown	0	87	93	100	100
Pentland Dell	0	87	93	100	100
Mean	0	80	95	98	100

Fig. 1

The effect of planting depth on the emergence of potato sprouts. Sprout number expressed as a percentage of the number present at the final harvest. Planting depths (■) 2.5, (▼) 5, (●) 10, (◆) 20 cm below the soil surface



Despite the occurrence of grass minimum temperatures of less than -8°C on several occasions only 20% of the tubers 2.5 cm below the surface were killed. In some cases the top part of the tuber was frosted but the tubers remained viable and sprouts grew from the underside.

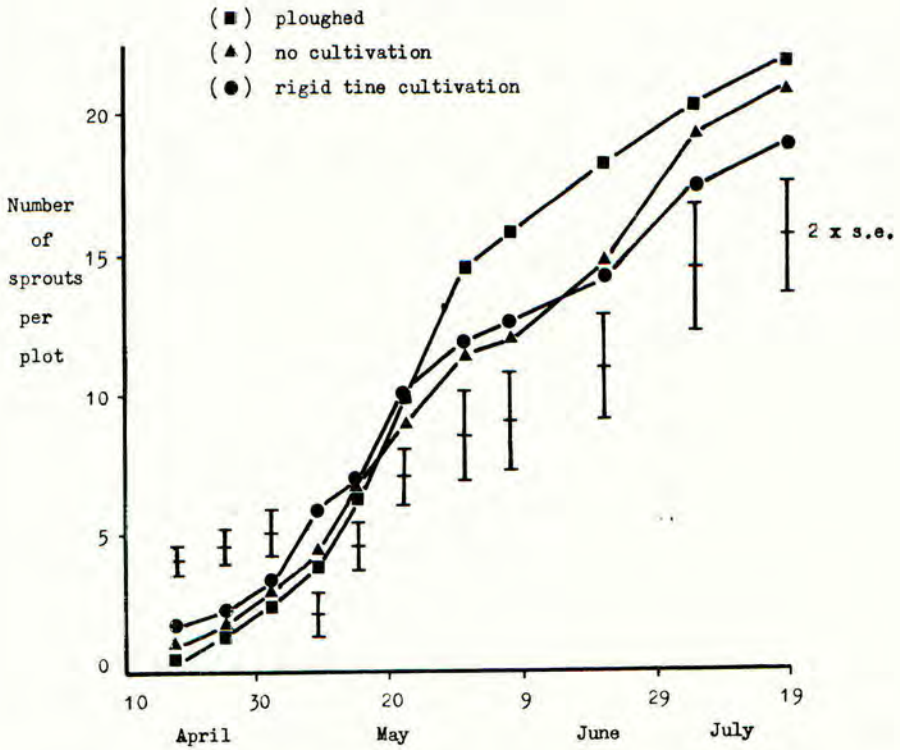
The emergence of sprouts from the surviving tubers was influenced by tuber depth (Fig. 1). There was also a slight effect of variety as further observations showed that sprouts from the King Edward tubers emerged slightly earlier than those from the other varieties. The tubers placed 20 cm below the surface reached 50% emergence 10 days after the shallowest tubers and reached 80% emergence 10 days after the tubers at all the other depths.

Cultivation experiment

Sprout emergence started in the middle of April and had ceased by the middle of July when the experiment ended. The type of autumn cultivation had no significant effect on sprout emergence (Fig. 2). However the presence of spring barley and

Fig. 2

The influence of the autumn cultivation treatments on the emergence of potato sprouts in the spring and summer



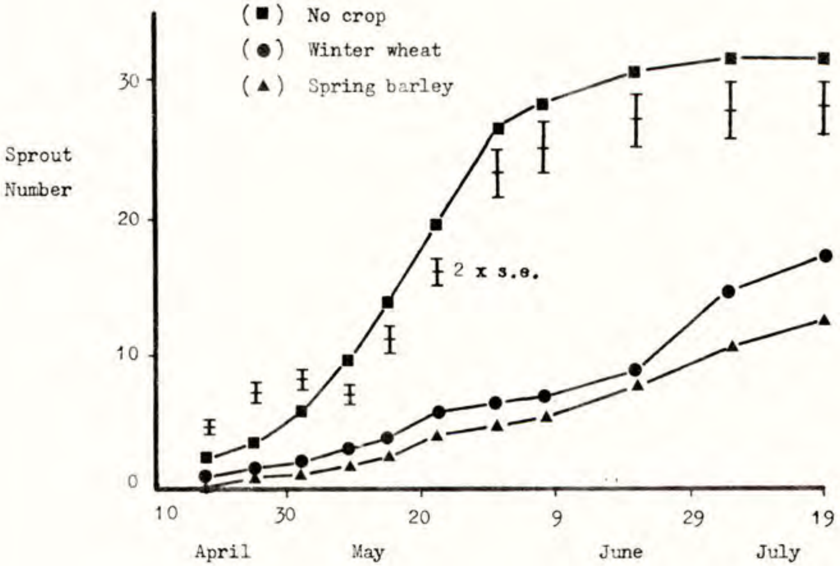
winter wheat drastically reduced sprout production (Fig. 3A). As well as reducing the total number of sprouts produced, the cereals delayed the emergence of the sprouts that were produced (Fig. 3B). On the plots sown with winter wheat 31% of the tubers produced plants, this increased to 39% on the spring barley plots and to 69% on the uncropped areas (Table 2).

The number of tubers producing plants was not affected by the three types of cultivation. However the depth of the tubers in the soil was significantly increased by ploughing and slightly increased by rigid tine cultivation (Table 3).

Fig. 3

The effect of winter wheat and spring barley on the emergence of potato sprouts

A) Number of sprouts per plot



B) Percentage of sprouts emerged

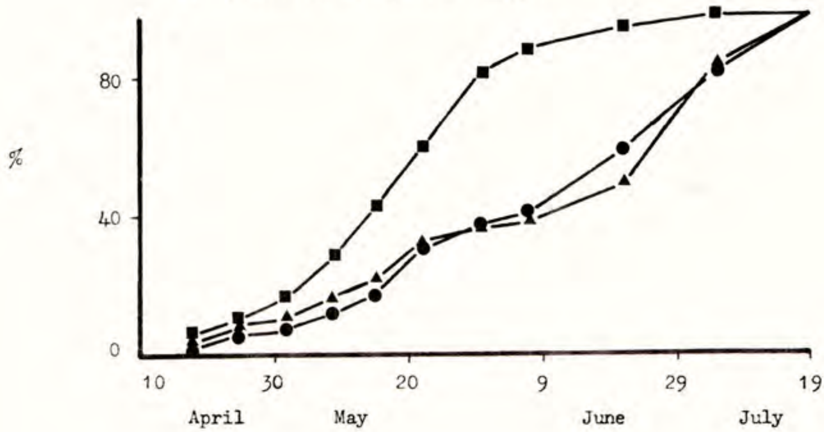


Table 2

The influence of spring barley and winter wheat on the number of potato tubers that produced plants and its modification by the method of cultivation used the previous autumn

Cultivation system	Cropping system			
	Winter wheat	Spring barley	No crop	Mean
Rigid tine cultivation	11.2 plants/plot	13.5	21.0	15.2
Ploughing	10.5	12.3	27.7	16.8
No cultivation	12.3	16.8	25.5	18.2
Mean	11.3	14.2	24.8	
Mean as % of total	31	39	69	

standard error of the individual plot means = 2.07

standard error of the overall cultivation and cropping system means = 1.19

Table 3

The effect of ploughing and rigid tine cultivation on the depth of tubers in the soil (cm) and its modification by the presence of a cereal crop

Cultivation system	Cropping system			
	Winter wheat	Spring barley	No crop	Mean
Rigid tine cultivation	6.9	6.2	6.1	6.4
Ploughing	10.8	11.9	14.5	12.4
No cultivation	6.0	4.5	5.2	5.2
Mean	8.0	7.5	8.6	

standard error of the individual plot means = 0.67

standard error of the overall cultivation and cropping system means = 0.38

DISCUSSION

The winters 1972-73 and 73-74 were very mild and hence only those tubers on or near to the soil surface were exposed to any very extreme temperatures. However under more severe winter conditions tuber depth and therefore the different cultivation methods used in the second experiment could have influenced survival considerably. The influence of the three types of cultivation on the depth distribution of the tubers was similar to that described by Lumkes and Beukema (1973) in an experiment designed to investigate the effect of ploughing and rigid tine cultivation on tuber distribution.

Some preliminary studies carried out during the winter showed that the soil temperatures at 5 and 10 cm below the surface were influenced by the previous cultivations, but more detailed studies are required to determine precisely how the temperatures of ploughed and unploughed soils react to atmospheric conditions. It is possible that the different soil structures produced by these cultivations influenced soil temperature, and perhaps tuber survival.

As well as potentially influencing survival, tuber depth was shown in the first experiment to affect sprout emergence, delaying that of the deeper tubers. This agrees with work carried out by Lewis and Rowberry (1973) and Moursi (1953) who showed that deep planted tubers emerged later than shallow planted ones. However these results were not repeated in the second experiment where the sprouts from the tubers in the ploughed plots (average depth 12.4 cm) did not emerge later than those in the uncultivated plots (average depth 5.2 cm). This would suggest that other factors were over-riding the influence of depth on emergence.

As the spring of 1974 was very dry (April 5 mm rain : May 27 mm rain) the emergence of potato sprouts may have been controlled by the water deficit rather than by the tuber depth. This would explain the low degree of sprouting that occurred during April and May particularly on the plots drilled with cereals which would have increased the water deficit. However during June (78 mm rain) and July (43 mm rain) the soil moisture level rose sufficiently to permit sprouting. But even under these more favourable conditions the rate of sprout emergence on the cereal plots remained low. This would suggest that if sprouting is limited by adverse environmental conditions for a long period the potatoes become unable to respond to improved conditions. Thus only 30-40% of the tubers on the plots drilled with cereals produced emerged sprouts whilst 70% sprouted on the bare plots.

Work reported by Chang (1958) and Carson (1961) showed that during the winter the presence of a winter wheat crop buffered the soil against the extremes of temperature thus protecting the potato tubers. In this experiment any beneficial effect exerted by the winter wheat during the winter was nullified during the spring and summer as both winter wheat and spring barley reduced survival by similar amounts. Further work is required to determine how these crops reduced survival.

Acknowledgements

I would like to thank the Potato Marketing Board for financial support for this work.

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EXPERIMENTS EXAMINING THE POTENTIAL OF TEN RESIDUAL HERBICIDES FOR THE CONTROL OF VOLUNTEER POTATOES

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Summary In two pot experiments 10 herbicides were applied either directly to potato tubers, or to the soil in which tubers were to be grown. In general the soil treatment was more effective than the direct tuber treatment. The results show that ammonium sulphamate, lenacil, metoxuron, propham and sodium chlorate did not significantly reduce the growth of the potatoes. Soil treatment with the higher doses of chlorpropham delayed sprout emergence and all doses of trifluralin, picloram, propyzamide and dichlobenil applied to the soil prevented sprout growth.

INTRODUCTION

The problem of volunteer potatoes has been increasing in importance over a number of years owing to changes in agricultural practices and to a series of mild winters. Potato tubers are extremely difficult to kill and most of the herbicides in current use are ineffective. Experiments by Lumkes & Sijtsma (1972) demonstrated that potatoes were resistant to most of the 27 post-emergence herbicides tested. However, little work has been carried out with pre-emergence herbicides apart from some experiments by MacNaeidhe (1972) which suggested that chlorpropham and prynachlor might be effective. From this data and from a study of the literature on the susceptibility of various vegetative perennating organs (eg. *Cyperus rotundus* tubers) to herbicides a number of candidate chemicals were selected. The two pot experiments described in this paper assess the susceptibility of potatoes to ten residual herbicides applied either to the tubers themselves or to the soil in which they were to be grown.

METHOD AND MATERIALS

Once grown, King Edward potato tubers 4-5 cm in diameter were treated with 7 doses of 10 herbicides (Table 1), using the W.R.O. laboratory pot sprayer with a single Teejet fan nozzle which delivered 304 l/ha at 207 kN/m^2. Two methods of herbicide application were used:

1) The potato tubers were placed under the sprayer and their upper surfaces were sprayed with the herbicides. The treated tubers were then planted in untreated sandy loam soil in 25 cm pots (7 tubers per pot) with their upper surfaces approximately 4 cm below the soil surface.

2) Soil contained in five metal dishes (19.0 x 13.7 x 7.6 cm) was sprayed with herbicide and was then thoroughly mixed. The treated soil was used to fill pots 25 cm in diameter and 21 cm deep. Seven tubers were planted in each pot 4 cm below the surface. It was calculated that a herbicide concentration of 1 g/m^3 in the soil would be produced by a dose of 1 kg/ha applied to the surface and incorporated uniformly to a depth of 10 cm.

In the first (glasshouse) experiment (sprayed 13.12.74) the pots were placed under glasshouse benches occupied by other experiments. The temperature was maintained at a mean of 15°C and the glasshouses were provided with supplementary lighting.

Table 1

Details of the treatments used in the two experiments

Herbicides	Doses: Soil applied g a.i./m³ Low	Medium	High	Tuber applied kg a.i./ha Low	Medium	High	Control
ammonium sulphamate	19.7	39.4	78.9	7.5	15	30	0
chlorpropham	2.63	5.26	10.5	1	2	4	0
dichlobenil	5.26	10.5	21.0	2	4	8	0
lenacil	2.63	5.26	10.5	1	2	4	0
metoxuron	3.94	7.89	15.8	1.5	3	6	0
picloram	0.13	0.26	0.52	0.05	0.1	0.2	0
propham	2.63	5.26	10.5	1	2	4	0
propyzamide	2.63	5.26	10.5	1	2	4	0
sodium chlorate	65.7	131	263	25	50	100	0
trifluralin	2.63	5.26	10.5	1	2	4	0

The effect of the herbicides was determined by recording sprout production over the next eight weeks. At the end of January or beginning of February the plants were harvested and the dry weight of haulm produced by the tubers in each pot was recorded. Finally the parent tubers were removed from the pots and their health was assessed. Those tubers in the pots containing treated soil that seemed healthy but had not sprouted were transferred to clean soil and any subsequent sprouting was noted.

In the second (outdoor) experiment (sprayed 16.1.74) the pots were placed outside after spraying and were covered with straw, to prevent frost damage, until the potatoes started sprouting (1.4.74) when it was removed. The effect of the herbicides was assessed by recording sprout production and by determining the dry weight of haulm present at the final harvest (4.6.74).

Both experiments were set out in randomised blocks and were replicated three times.

RESULTS

Glasshouse experiment Sprout emergence in the control and some of the treated pots had started by the twentieth day after planting. The controls and many of the treated tubers produced shoots that grew rapidly and attained a considerable size by harvest. The dry weight data from the final harvest showed that those potatoes treated with trifluralin, picloram, propyzamide and dichlobenil produced little or no haulm; soil treatments being more effective than tuber treatments (Fig. 1). Picloram applied directly to the tubers caused the production of deformed sprouts with rudimentary leaves and thick stems. The two higher rates of chlorpropham and sodium chlorate

Figure 1

The influence of several doses of ten herbicides on the dry weight of potato haulm. Data expressed as a percentage of the controls. (--------) tuber applied (kg a.i./ha); (————) soil applied (g a.i./m^3)

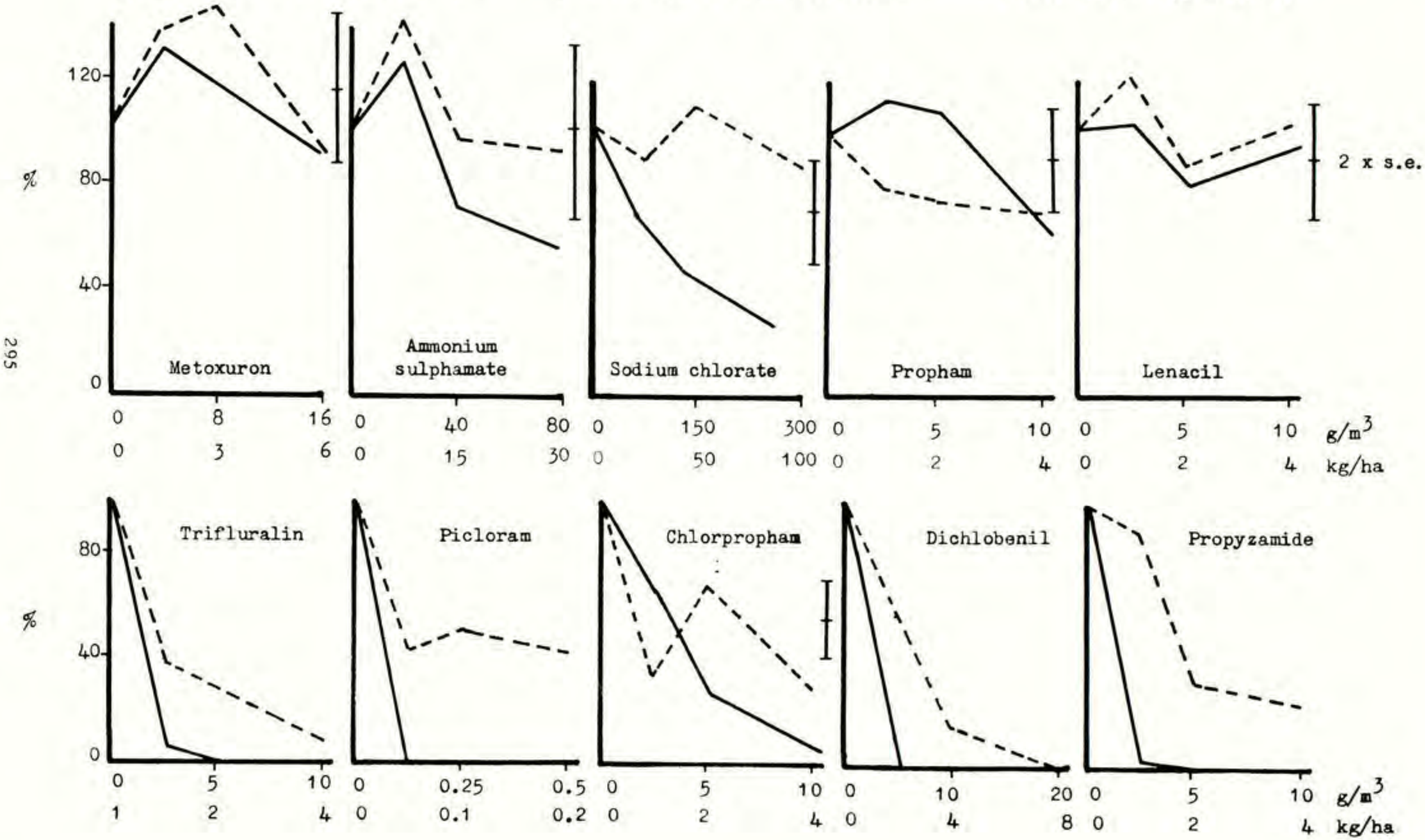
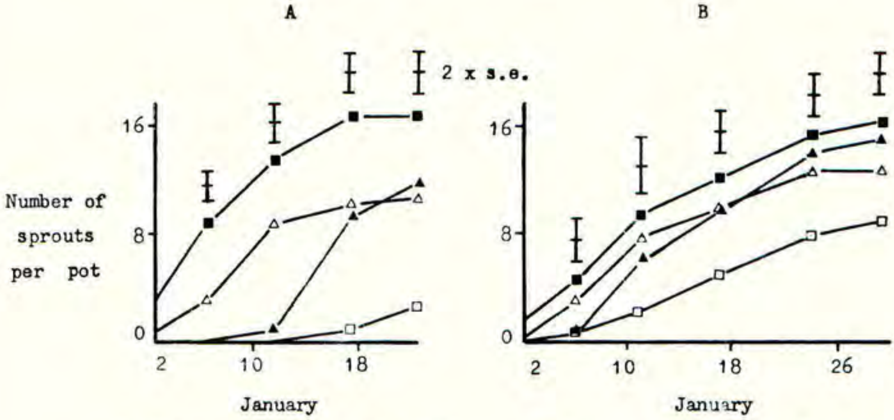


Fig. 2

The influence of soil applications of (A) chlorpropham and (B) sodium chlorate on the emergence of potato sprouts (Experiment 1)



(■) 0, (△) 2.63, (▲) 5.26, (□) 10.5 g a.i./m^3

(■) 0, (△) 65.7, (▲) 131, (□) 263 g a.i./m^3

applied to the soil delayed sprout emergence which led to lower haulm production (Fig. 2). This was particularly noticeable at the highest rate of chlorpropham. The remaining four herbicides, ammonium sulphamate, metoxuron, lenacil and propham did not significantly reduce the growth of the potato plants.

Many of the tubers treated with dichlobenil and picloram had rotted by the end of the experiment but those treated with trifluralin and propyzamide, despite the absence of sprouts, appeared healthy (Table 2). These healthy looking tubers were repotted in clean soil. Four weeks later most of them had produced emerged sprouts.

Outdoor experiment The potato sprouts in this experiment did not start to emerge until 1.4.74, seventy five days after planting and did not grow as quickly as those in the glasshouse experiment. As in the first experiment dichlobenil, picloram, propyzamide and trifluralin had the greatest effects on the potatoes, and those tubers growing in soil treated with these herbicides produced almost no haulm (Table 3). The soil treatment with chlorpropham also reduced haulm production, as did propham at its highest rate, but these two herbicides were not nearly so effective as the previous four. However they did significantly delay the emergence of sprouts at their higher doses (Fig. 3).

Those tubers treated with picloram produced deformed plants. In addition, the higher doses of lenacil caused the production of chlorotic plants and the potatoes treated with the higher doses of sodium chlorate had small crinkled leaves. However these two herbicides together with metoxuron and ammonium sulphamate did not significantly reduce the growth of the potato plants.

Fig. 3

The influence of soil applications of (A) chlorpropham and (B) propham on the emergence of potato sprouts (Experiment 2)

(■) 0, (△) 2.63, (▲) 5.26, (□) 10.5 g a.i./m^3

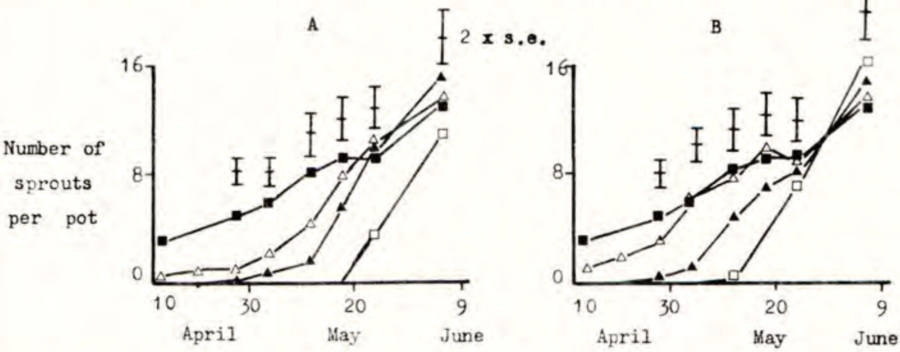


Table 2

The effect of the ten herbicides on the percentage of healthy tubers present at the final harvest (Experiment 1)

Herbicides	Soil applied Low	Soil applied Medium	Soil applied High	Tuber applied Low	Tuber applied Medium	Tuber applied High	Control
ammonium sulphamate	95	90	95	90	100	100	98%
chlorpropham	95	100	100	95	100	100	100
dichlobenil	0	5	0	76	57	0	98
lenacil	95	100	95	100	100	100	100
metoxuron	100	100	100	100	100	95	98
picloram	67	43	10	81	90	71	98
propham	100	100	95	100	100	95	98
propyzamide	57	62	71	90	71	43	100
sodium chlorate	95	100	95	95	100	95	100
trifluralin	86	90	71	100	100	95	98

Table 3

The effect of six doses of the ten herbicides on the dry weight (g) of haulm produced by the treated potato tubers (figures in brackets = log x + 1)

Herbicide	Doses					
	Soil applied			Tuber applied		
	Low	Medium	High	Low	Medium	High
ammonium sulphamate	12.4(1.12)	14.5(1.15)	14.7(1.20)	14.6(1.19)	16.2(1.22)	14.7(1.20)
chlorpropham	13.9(1.17)	10.8(1.06)	5.3(0.79)	11.6(1.08)	10.4(1.06)	5.7(0.78)
dichlobenil	0 (0)	0 (0)	0 (0)	9.4(0.99)	2.0(0.45)	0.6(0.15)
lenacil	16.5(1.23)	10.8(1.06)	13.6(1.16)	12.9(1.14)	17.9(1.27)	18.0(1.27)
metoxuron	15.9(1.23)	14.3(1.17)	18.8(1.28)	17.4(1.26)	17.1(1.25)	13.4(1.15)
picloram	2.0(0.39)	1.2(0.30)	0 (0)	11.8(1.11)	9.9(1.04)	6.2(0.86)
propham	15.2(1.21)	12.1(1.11)	9.4(1.00)	15.9(1.22)	14.7(1.19)	13.7(1.26)
propyzamide	0.9(0.24)	0 (0)	0 (0)	11.6(1.10)	9.8(1.01)	4.3(0.72)
sodium chlorate	16.1(1.23)	16.3(1.24)	15.0(1.20)	17.2(1.26)	17.5(1.26)	14.8(1.19)
trifluralin	0.1(0.04)	0 (0)	0 (0)	7.9(0.94)	4.9(0.75)	2.5(0.30)
control			16.8(1.24)			

Standard error for the treatments: means of 3 replicates (log data) = 0.062

Standard error for the controls: means of 30 replicates (log data) = 0.020

DISCUSSION

Residual herbicides for the control of groundkeeper potatoes could be applied in the autumn or in the late winter and early spring. If a herbicide was applied in the autumn when soil conditions were suitable for spraying, most of the chemical might be lost by the spring and would thus be ineffective on the newly sprouted potatoes. Soil and weather conditions in the late winter may prevent the successful application of a herbicide and in addition the chemical might pose persistence problems in the subsequent crop. In the first (glasshouse) experiment good conditions for potato sprout growth were provided, whilst in the second (outdoor) experiment the conditions were less favourable and simulated a field application of herbicide in January. The results show that experimental conditions had little effect on herbicide toxicity as the chemicals showed similar levels of activity in both trials.

The data for most herbicides showed that the soil treatments were more effective than the direct tuber treatment. This was somewhat surprising as tubers sprayed with herbicide would have been exposed initially to a higher concentration of chemical. But in the soil treated pots the herbicides were more readily available for uptake by the roots of any developing sprouts, thus perhaps accounting for their greater activity.

Soil treatments with trifluralin, propyzamide, picloram and dichlobenil, the four most effective herbicides, prevented the potatoes sprouting at all doses. Picloram and dichlobenil killed the parent tubers. However, trifluralin and propyzamide appeared only to inhibit sprouting as the unsprouted tubers transferred to clean soil sprouted readily. Thus conditions conducive to the rapid loss of herbicides from the soil would reduce the activity of these two chemicals. Chlorpropham also showed some activity in both experiments reducing sprout production, particularly at its highest dose. The remaining herbicides despite their activity against many weeds, were ineffective on potatoes.

It is unlikely that the excellent control of potatoes by picloram and dichlobenil in these experiments could be practically exploited because of their persistence. However the results achieved with trifluralin, propyzamide and perhaps chlorpropham suggest that practical control measures using these herbicides could be developed. Further field trials are necessary to determine the potential of these three herbicides for groundkeeper control.

Acknowledgements

I would like to thank the Potato Marketing Board for financial support during this study.

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NOTES

SUGAR BEET AS A WEED

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Summary In addition to groundkeepers, seed washed inland by floods and that shed by seed crops, sugar beet may become a weed through seed production by bolters in the root crop. Recently this has happened with beets of annual habit which can each produce about 150 viable seeds. Direct drilling of the following crop should stimulate most of the shed seed to germinate so they can be killed by surface cultivation. Ploughing to depth seems to prolong the life of the seed. Wide rotations and effective herbicide spray programmes in cereals should help to control all forms of sugar beet weeds. Prevention of seed production by bolters in the sugar beet root crop was achieved in field experiments by cutting off, pulling up or making glove applications of a 10% glyphosate solution during the first few days in July. The glyphosate damaged other plants which it reached by drip.

Résumé La betterave peut se transformer en mauvaise herbe non seulement suite a la présence dans le sol de fragments de racines, de graines apportees par les crues ou provenant des champs de porte-graines, mais encore par les betteraves montées à graines dans la culture. On a récemment observé que des betteraves sauvages peuvent produire chacune jusqu'à 150 graines viables. Par le semis direct de la culture suivante, on devrait stimuler la germination de la plupart des graines tombées sur le sol de manière a pouvoir les détruire ensuite par un travail superficiel. Le labour en profondeur parait prolonger la vie de la semence. De longues rotations complétées par des applications judicieuses d'herbicides en cereales devraient contribuer a détruire tous les types de betteraves sauvages. Dans champs experimentaux, l'on a pu prévenir la production de semences par les betteraves montées À graines en les étêtant, ou les arrachant, ou en appliquant, au gant, une solution de 10% de glyphosate durant les premiers jours de juillet. Le glyphosate a causé des dégâts à d'autres plantes atteints par des gouttes.

INTRODUCTION

There are several ways in which sugar beet becomes a weed including :
(1) Tops with a large amount of crown attached or entire beets left in the field after harvest which overwinter and grow in the following season. Many such groundkeeper plants will be killed by desiccation or by frost if they lie on the surface. Some may be eaten by birds or animals, in particular rats, but up to 200 plants/ha have survived on occasion at Broom's Barn. They pereneate pest and disease and may flower and set viable seed which is shed onto the ground. Since cereals follow sugar beet in most rotations these beets can be controlled by selective weed killers.

(2) Wild beets might be thought to represent a weed hazard. They grow on the sea shores of England, particularly in the sugar-beet root crop areas of East Anglia from the Wash to Essex. However, even after the severe east coast flooding of 1953, which brought much wild beet seed inland, the species (Beta maritima and B.maritima x B.vulgaris crosses) failed to establish themselves in competition particularly with grass and had disappeared within a few years (Blencowe, 1956, 1957, 1958). This is fortunate since many were prolific seed producers. These plants are a potential hazard to sugar-beet seed crops since not only do they harbour pests and diseases but they are able to cross fertilise with cultivated sugar beet (B.vulgaris). This would lead to deterioration of cultivars, particularly by introducing the undesirable dominant character for annual habit. However, this has not occurred, perhaps because the dense pollen clouds produced by seed crops give the wild pollen little chance of fertilising. It should be possible to control the wild beets chemically along the sea shore. However, after an area had been cleared, wild beet was the first species to recolonize the land. Its control is not now attempted; to eradicate it all the coastline would have to be sprayed for several years.

(3) In order to obtain sugar-beet seed of the greatest possible quality harvesting is often delayed until the onset of seed shedding. Under some circumstances up to 125 kg/ha seed may be lost, i.e. 12.5 million seeds/ha are shed. At Broom's Barn such areas have produced a crop of beet seedlings in each succeeding year for seven years so far. They are controlled effectively by weed killers applied to cereal crops but they persist as a weed in other beet seed or root crops in the rotation. Tests are being made to see if shallow surface cultivation in the autumn and direct drilling of cereals will germinate these seeds quickly so they may be killed. Ploughing them in seems to prolong their survival and allows some to germinate each year for many seasons.

(4) Recently, a new form of sugar-beet weed has appeared - the root crop bolter which produces viable seed. These are the main subject of this paper and are of two distinct types, A and B. Each must be clearly distinguished.

A. The first type arises from new varieties which tend to bolt. This, coupled with the fact that in recent years farmers have sown progressively earlier to lengthen the crop growing season, has exposed bolting susceptible seedlings to cool conditions. Many have bolted and although triploid plants are normally sterile, the diploid ones are fertile and some produced viable seeds which were returned to the soil. However, these are normal sugar-beet types and are to be expected to be biennial in habit. Their control should be easy and effective in intervening cereal crops.

B. The second type is a consequence of pollen contamination by wild beets of annual habit as frequently found in southern Europe. Much monogerm seed is produced using diploid (2n) male sterile monogerm mother plants fertilised by pollen from tetraploid (4n) multigerm father plants. Only the hybrid triploid (3n) monogerm seed is used. Scott and Longden (1969) showed that each day diploid plants liberate pollen about 2 hours in advance of tetraploids. This is because diploid plants release pollen at a relative humidity (RH) of about 95%, whereas tetraploid plants do not do so until the RH has dropped to about 75%. Thus, when seed crops using tetraploid pollinators were grown in areas where diploid wild beet grew (both B.vulgaris and B.maritima as well as crosses), crossing with the wild occurred. Seed growing localities are now more carefully selected, and the seed is kept an extra year to screen for bolters before selling. The problem should not occur again.

Because the wild beets were of annual habit and this character is dominant, (McFarlane, et al., 1948) some seed sold to farmers in England in 1969, 1970 and 1971 produced some plants which bolted immediately and set seed. Characteristically these annual bolters are very variable but most are thinner and more spidery than the normal bolter, often with red or yellow coloured petiole bases. They have long inflorescences with many flowers. By 1972, 1973 and 1974 some fields were again in beet and produced many beet seedlings in patches, presumably where seed had been shed by bolters in the preceeding root crop. These bolted almost immediately and set viable seed.

It is very difficult to identify a true annual bolter from an early bolting biennial type. Thus, any control measures will have to be applicable to both types. We have not tried to separate them in the rest of our work which sought to find out the extent of the problem, the potential for its increase, and how to effect control.

METHODS AND MATERIALS

Identification

Seed of a variety of sugar beet known to be of biennial habit when grown in England (Battles E) was sown in compost in pots at Broom's Barn on 16 April 1974. Seed of an annual wild type collected in Italy, and from bolted plants in a root crop grown in England in 1973 was also sown. On 3 May all pots were moved outside to give a cool stimulus during the nights to induce bolting, and then returned to the glasshouse on 20 June. On 10 July the number of plants with red, yellow or green petioles were counted and also the number that had started to bolt (stems elongated).

Extent of the problem

Staff of the British Sugar Corporation, Peterborough, surveyed fields growing sugar beet in 1973. Volunteer annual bolters were identified because of their red or yellow colouring and/or because they occurred between the rows of sown seed. The number and area of the affected fields was recorded, but not the degree of infestation within each field.

Potential increase

This was studied by harvesting seed from root-crop bolters (cv. Monotri) on 12 November 1970, and of cv. Monobeet on 10 August 1973. By harvesting late in 1970 we hoped to get the most mature seed possible; by harvesting in August 1973 we aimed at assessing the viable seed production at a time when farmers might assume all plants which would bolt had done so and might therefore be ready to practice a control measure. For both seed lots the number of seeds produced per bolter were determined and their viability assessed by laboratory germination in pleated filter paper (Hibbert & Woodwark, 1969).

Control of bolters

A preliminary trial showed that stalks cut off on 10 August 1973 and left on the field produced on average 12 viable seeds per bolted plant. In a glasshouse screening trial in 1974, 4ml water or glyphosate solution was sprayed onto bolting plants at 0, 5, 10 or 15%. The two top rates killed the beet within two weeks of spraying and 5% did after about four weeks. On the basis of these trials attempts were made in three field experiments in 1974 to control bolters by cutting off inflorescences, or pulling up plants or by glyphosate application. At Ely, Cambridgeshire, bolters were cut off or pulled up or treated with a rogueing glove which applied, in one squeeze, 1ml/plant of 10% glyphosate solution. Treatments were applied either on 1 July or 22 July or both. At Lackford, Suffolk, bolters were cut off or treated with 1ml/plant of glyphosate solution at 10% or 20%. Treatments were applied on 2 July or 23 July or on both occasions. At Barnham, Norfolk, on 15 July, bolters were cut off or pulled up or treated with 1ml of 10% glyphosate solution per plant. All three experiments were of randomised replicated design and included nil treatment controls. Plot size aimed to include 70 to 100 bolters and ranged from 4 rows of plants x 30m long at Barnham to 4 rows of plants x 110m at Lackford. Bolted plants were harvested on 6 August (Barnham), 7 August (Ely) and 8 August (Lackford). After drying, the seed was threshed off, cleaned and three replicates of 50 seeds were tested for germination in the laboratory in pleated filter paper (Hibbert & Woodwark, 1969).

RESULTS

Identification

This test showed that seed from bolters in a root crop gave plants which grew like plants from seed of an Italian wild annual beet. Also, annual bolters produced seed which grew into annual bolters. These annual bolters tended to give more plants with red coloured petioles than did the biennial cultivated variety (Battles E) but this could not be used as a provenance test since all three types of seed gave some plants with all colours of petioles (Table 1).

Table 1

Bolting by different types of seedlings grown in pots in a glasshouse at Broom's Barn in 1974

Seed lot	Percentage of plants which bolted	Percentage of plants whose petioles were Red	Yellow	Green
Battle's E harvested at Broom's Barn in 1973	0	7	3	90
Wild annual beet harvested in Italy in 1971	99	50	20	30
Seed from bolters harvested in root crop near Bury St. Edmunds in 1973	75	82	12	6

Extent of the problem

The survey by the B.S.C. showed that, out of 180000 ha of root crop grown in 1973, 33 fields totalling 312 ha had volunteer beet seedlings in them.

Potential increase

Monotri bolters harvested on 12 November 1970 gave, on average, 146 viable seed per plant. The monobeet bolters harvested on 10 August 1973 gave 12 viable seed per plant. Table 2 shows how many viable seeds are likely to be produced at these different levels of production with different percentages of bolters. Observations suggested that about half the plants which are bolted (i.e. showed some stem elongation) in early July produced viable seed.

Control

The three field experiments were characterised by large statistical errors. Nevertheless, at Ely all treatments significantly decreased seed production. Cutting both on 1 and 22 July, glove treatment with glyphosate on 1 July and both 1 and 22 July, pulling up bolters on 1 July and both 1 and 22 July completely prevented seed production. Treatments on 1 July or 1 and 22 July also tended to reduce viability of any seed which was produced (Table 3).

Table 2

Production of viable seed by sugar-beet root crop bolters

Plants producing seed (%)	Viable seeds produced/ha at 12 viable seeds/plant	Viable seeds produced/ha at 146 viable seeds/plant
0.1	9000	109500
1.0	90000	1095000
5.0	450000	5475000

Table 3

Bolter control in root crop near Ely, Cambridgeshire, 1974

Treatment	Number of seeds produced per bolted plant	Number of viable seeds produced per bolted plant by 7 August
Nil	241	1.61
Bolters cut off 1 July	13	0.14
" " " 22 July	40	0.14
" " " 1 July and again 22 July	0	0
1ml 10% glyphosate 1 July	0	0
" " " 22 July	46	1.51
" " " 1 July and again 22 July	0	0
Bolters pulled up 1 July	0	0
" " "22 July	54	0.22
" " " 1 July and again 22 July	0	0
S.E. ±	38.1	0.558

At Lackford, cutting down the bolters and glove treatment both early and late with glyphosate significantly reduced seed production. Cutting on 2 July and glove treatment with glyphosate on 2 July and again 23 July completely prevented seed production. Again viability tended to be reduced by treatments which were made on the earlier date, 2 July (Table 4).

At Barnham, although all treatments applied on 15 July reduced seed production, none completely prevented it. Seed viability tended to be reduced, particularly by glove treatment with glyphosate (Table 5).

Table 4

Bolter control in root crop near Lackford, Suffolk, 1974.

Treatment	Numbers of seeds produced per bolted plant	Numbers of viable seeds produced per bolted plant by 8 August
Nil	56	1.69
Bolters cut off 2 July	0	0
" " " 23 July	8	0.09
" " " 2 July and again 23 July	9	0.09
1ml 10% glyphosate solution/plant 2 July	35	0.02
" " " 23 July	34	0.82
" " " 2 July and again 23 July	1	0.50
1ml 20% glyphosate solution/plant 2 July	26	0.24
" " " 23 July	17	2.11
" " " 2 July and again 23 July	0	0
S.E. ±	11.0	0.620

Table 5

Bolter control in root crop near Barnham, Norfolk, 1974.

Treatment applied 15 July	Number of seeds produced per bolted plant	Number of viable seeds produced per bolted plant by 6 August
Nil	284	0.65
Bolters cut off	83	0.33
Bolters pulled up	60	0.23
1ml 10% glyphosate solution/plant	54	0.09
S.E. ±	36.4	0.031

DISCUSSION

Annual bolters could only be definitely identified as such by collecting and sowing seed from them and observing the growth of the progeny. However, many annual bolters had yellow or red markings at the bases of their petioles and many had long thin inflorescences and bolted early when their root system was very small.

At present only a small area of arable land amounting to about 0.16% of the sugar-beet area each year, is known to be seeded with annual bolting beet. However, much sugar beet is grown in England in a four or five course rotation so it is possible that about 1200 ha are affected. This type of rotation with intervening cereal crops sprayed with growth regulator herbicides offers a potentially effective control and has almost certainly restricted the problem. In some European countries, where a two course rotation is practiced with beet alternated with barley, the problem is much worse. In areas of France there are prospects that beet growing will have to be abandoned because of volunteer annual bolting beets (Boiteau, et al., 1974).

The potential seed multiplication is large. At present there is little chance of spreading seed from existing infected fields.

Control of annual beet in fields which are already infested must be done rigorously and carefully if this weed is to be controlled. If not controlled, it may become impossible to grow sugar beet on these fields. In our experiments the key to success seemed to be to control bolters in the first few days of July. At this time cutting, pulling and glove treatment all effectively prevented seed production. By 15 July some seeds had been produced and a few of these were viable. By early August many plants had produced viable seeds. If left until root crop harvest in early November the viability is likely to have risen by about the 1% per day increase noted in the seed crop (Longden and Scott, 1973). Thus, the uncontrolled plants at Ely and Barnham could each have produced about 200 viable seeds.

Successful control must aim at preventing seed production. Pulling was effective if done early but is tedious and slow hand work; presumably it could be mechanised if sufficient area of crop needed to be treated. Glove treatment was rapid and effective if done early but glyphosate dripped onto adjacent non-bolted plants killed them also. We suspected that some movement of this chemical took place between adjacent plants. A less mobile chemical may be more successful. Topping was also effective if done early and this is a treatment which can readily be mechanised by using existing weed cutting equipment. (The green weed topper made by Ramsey Ltd., Hollow Road, Forty-Foot Bridge, Huntingdon, Great Britain, can cut about 6.5 ha per hour.)

At present the most promising control method to prevent bolters in sugar-beet root crops from producing seed is to cut down all bolted plants during the first few days of July. It should be possible to control them with selective herbicides in cereal crops in the rest of the crop rotation.

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VOLUNTEER CROP PROBLEMS IN THE PROCESSING INDUSTRY

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Summary The results of a survey carried out in 1974 amongst processors and grower groups, indicated that the most serious 'volunteer' problem was potatoes occurring in leguminous crops and in carrots and calabrese grown for processing. In terms of acreage the vining pea crop had the largest acreage affected (approx. 12,000). Although the area affected by potatoes in the other crops was less, it still constituted a significant percentage of the total acreage. 'Self set' mustard was the next most commonly occurring 'volunteer' problem.

The effects of 'volunteers' on the production, yield, quality and processing of the major vegetable crops are discussed and the major importance to the processor of possible produce contamination in leguminous crops is emphasized.

INTRODUCTION

Husbandry techniques used in the production of vegetable crops, grown specifically for processing, have improved considerably over the past ten years and linked with increasingly more effective chemicals, have been responsible for the general decline of problems caused by weeds, pests or diseases. Over the past few years, however, increasing problems have been encountered throughout the industry caused by 'volunteers.' The difficulty in avoiding or controlling the problem and the serious effects of them on the crop and to the grower and processor, make this probably the most important production problem facing the industry at the present time. In this paper the effects of 'volunteers' on the growing, harvesting and processing of the most widely grown processed crops will be examined and the results presented of a survey carried out on their occurrence.

1. The extent of the problem

In 1974 the Processors & Growers Research Organisation carried out a postal survey amongst its processor and growers group members, to try to establish the percentage of crops currently affected by 'volunteers' and to request information regarding their significance to the grower and processor. The results of this survey, in which 12 companies supplied data, are summarised in Table 1.

Table 1
Survey results

Volunteer crop	No. of companies affected Crop ≁						Av. % of acreage affected Crop ≁					
	VP	DB	BB	CA	CL	BS	VP	DB	BB	CA	CL	BS
Potatoes	11	6	6	2	1	1	12	14	16	22	20	2
Sugar beet	1	0	0	0	0	0	2	0	0	0	0	0
Rape	2	0	0	0	0	0	8	0	0	0	0	0
Mustard	2	1	1	0	0	0	3	5	15	0	0	0
Wheat	1	0	0	0	0	0	1	0	0	0	0	0
Kale	1	0	0	0	0	0		0	0	0	0	0

VP Vining peas
DB Dwarf beans
BB Broad beans
CA Carrots
CL Calabrese
BS Brussels sprouts

≁ No data available for dried peas or navy beans.

It will be seen that potatoes are the most important volunteer occurring in all the six processing crops included in the survey and particularly serious in peas and beans. While the survey did not cover the whole of the acreage for these crops it was nevertheless considered representative and assuming that this is the case the acreage of vining peas affected by potatoes would be approximately 12,000 per annum and that of dwarf and broad beans approximately 3,000 and 1,500 acres respectively. Approximately 20% of the carrot and calabrese crops grown for processing were affected by potatoes, which in the case of carrots would amount to approximately 1,700 acres per annum. The present acreage for calabrese is relatively small while the size of the acreage of brussels sprouts affected by potatoes no doubt reflects the different husbandry methods used in the production of this crop. 'Self set' mustard was the next most commonly occurring 'volunteer' being found in peas and beans while peas stand out as having the greatest range of 'volunteer' problems.

The survey shows that an unacceptably high percentage of the major processing crops are now affected by volunteers, mainly potatoes, and when one considers that over 16,000 acres of peas and beans are involved the magnitude of the problem can be appreciated.

2. The effects of 'volunteers' on processing vegetables

a. The effect on crop growth and yield

'Volunteers' can cause serious competition to crop plants during growth. Dwarf and navy beans, carrots and on occasions peas and brassicas such as calabrese can be completely swamped by 'volunteer' potatoes, which unless removed severely reduce crop growth and yield. Tall vigorous crops such as broad beans, are more capable of competing with 'volunteers.' The species of 'volunteers' present and the severity of the infestation are obviously of importance in respect to the amount of competitition imparted and experience suggests that potatoes are generally the 'volunteers' which are likely to cause the most serious problem.

The effect of competition from weeds or 'volunteers' can be particularly serious in processing crops where production methods and conditions are carefully controlled so that the harvested produce meets the processors quality standards in respect of maturity and size grade. The effects of weed competition on size grade distribution within the harvested crop and on the relative maturity of crops was discussed in some detail in a paper presented at the previous conference, (King 1972), and there is little doubt that 'volunteers' can be considered in the same context as weeds in this respect. Thus the competitive effect could be to alter the proportion of the carrot, red beet, onion or calabrese crop falling in the desired grade, while the maturity of crops such as peas and beans could be materially affected, thus disrupting the harvesting programme and possibly causing the crops to be by-passed.

b. The effect on harvesting

The majority of processing crops are mechanically harvested and the presence of large quantities of green material can significantly reduce the efficiency of the operation. This is particularly true in crops where combines or viners are used. The total bulk of green material passing through the drum of a pea or broad bean viner determines the capacity of the machine and the expedient of increasing the speed cannot be carried out without increasing produce damage and losses through the machine. Therefore the presence of volunteers in such crops has the effect of slowing down vining and reducing the output of vined produce (Elliot 1972). When the vining schedule is tight affected crops may well be by-passed in favour of cleaner ones, (Gane 1972). The efficiency of cutting can also be affected by 'volunteers'. Similar problems occur during the mechanical stripping of dwarf beans, while to avoid green plant material affecting the combining of dried peas and navy beans a pre-harvest desiccant may be necessary. In carrots the removal of haulm prior to lifting prevents volunteer plants interfering with the harvesting operation, but in other crops where hand harvesting is still carried out volunteers naturally slow down the rate of picking.

c. Contamination problems

While the effects of 'volunteers' on growth, yield, quality and harvesting are extremely important to grower and processor alike, the possibility of contamination with extraneous matter is by far the most important aspect of 'volunteers' in processing crops. The Pure Foods & Drug Act of 1955 states that the content of a packet of processed food must be declared on the outside and must not contain extraneous vegetable matter of any kind, this then is the standard of the final pack required by the processor. Whilst the Public Health Inspector might take a lenient view with respect to contamination of peas with such things as pods he would definitely take stringent action if the product was contaminated with weed, (or other plant) material (Elliot 1972). This then is the problem and probably the most troublesome volunteer in this respect is potatoes in vining peas, broad beans or dwarf beans. They cause problems for the following reasons.

i. In fertile varieties the green potato berries or 'apples' are of similar size, shape and density to peas or broad beans and may well pass through all the cleaning operations with the produce.

ii. Small tubers occasionally contaminate peas and broad beans in a similar way.

iii All parts of the potato plant contain toxins and thus any extraneous matter may be classed as toxic in nature.

iv. Removal of berries and debris from peas and beans may be possible during the final inspection, but if such matter is present in dwarf beans during slicing subsequent removal is virtually impossible.

If a contaminant is found in a batch of packets or cans the whole batch is rejected, together with the rest of the unharvested crop, and in practice the processor takes care to avoid these problems by either asking for the crop to be hand-weeded prior to harvesting and if this cannot be done rejecting it.

This causes a considerable financial loss to both grower and processor.

Contamination problems are much less likely to occur in the non-leguminous processing crops, with the possible exception of spinach.

d. Prevention or control of 'volunteers'

In the case of vegetables grown on contract the processor has a good deal of control in their production. Adequate rotation must be practised for peas and beans which necessitates choosing land which has not grown leguminous crops in the previous three or four seasons. Since potatoes are known to be a problem, two, three or even four years after the original crop was grown, and there is evidence that they are particularly troublesome in the second or third year, processors and growers have great difficulty selecting sufficient acreage where they can be reasonably sure of avoiding the problem. Whenever possible they try to reject fields where the variety of potato was one which produces berries to avoid contamination problems, but it was reported in the survey that some fields now contain more than one variety of volunteer potato.

Control of certain 'volunteer' crops in vegetables is exceedingly difficult, if not impossible and the best that can usually be achieved is partial control or suppression. This may be sufficient to enable satisfactory growth and harvesting to be carried out and to avoid contamination of produce. In peas the post-emergence application of dinoseb will only suppress 'volunteer' potatoes, although less important 'volunteers' such as mustard and rape can usually be controlled by chemical means if recognised in time. Growers have found that late applications of dinoseb, made after flowering, are relatively safe to the crop and severely suppress potatoes to the extent that they do not unduly interfere with harvesting or produce berries. Similar treatment does not appear possible in broad beans and in dwarf and navy beans the only selective post-emergence treatment available, bentazone, has little effect on potatoes. Inter-row vibra jet applications of paraquat will usefully suppress those plants in the inter-row area, but hand weeding has to be carried out in the rows. In dried peas and navy beans pre-harvest desiccation with diquat has proved a valuable aid in preventing 'volunteers' interfering with harvesting. In carrots useful control of 'volunteer' potatoes can be achieved from post-emergence applications of metoxuron, but if this fails mechanical weeding of carrots grown in beds cannot be carried out and hand weeding is difficult and damages the plant stand. In brassica crops post-emergence treatment for volunteers is not possible, except for those grown in wide rows where vibra jet applications or mechanical cultivations can be carried out.

In general most chemical treatments are only partially successful and hand weeding has to be resorted to in those crops where this is feasible. In vining peas and broad beans this may not be possible and crop rejection is then the only remedy.

CONCLUSIONS

The extent of 'volunteer' problems in processing vegetable crops has now reached serious proportions, affecting many thousands of acres annually and causing major problems in the growing, harvesting and processing of the crops. Due to the longevity of the problem, for example volunteer potatoes, it is virtually impossible for the processor to avoid growing some of his crops on land where there is a risk of volunteers appearing and control measures are not at present very effective. The costs incurred in hand weeding and the losses involved if the crops are rejected, considerably reduce the profitability of growing processing vegetables. Processors can prevent the final packs becoming contaminated by debris from volunteers, but at a high cost in terms of increased inspection or loss of produce due to crop rejection. If target tonnages are not achieved the overall profitability of the company is reduced. There is a very real need for measures which will help to reduce 'volunteer' problems in these crops before the situation worsens even further.

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NOTES

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THE CONTROL OF RASPBERRY SUCKERS IN UNCULTIVATED PLANTATIONS

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Summary Techniques were examined for the control of raspberry suckers growing in the alleys of uncultivated plantations. Cutting in late spring and early summer stimulated further emergence unless carried out just before fruit harvest. Cutting suckers whenever they reached 15 cm or 30 cm height required three and two cuts before harvest respectively. Different cutting regimes repeated for three years had no effect on growth or yield in the crop rows and relatively little effect on numbers of suckers emerging each spring. In all experiments emergence was largely completed by the time suckers had reached 15 cm. Discing to a depth of 13-18 cm alongside the crop row to sever root connections had no adverse effect on cane or fruit production in the rows, and largely prevented translocation to the row of herbicides applied to sucker foliage in the alley. Glyphosate and aminotriazole were the most effective of a wide range of herbicides evaluated for sucker control.

INTRODUCTION

Raspberry canes are not normally thought of as weeds, although their appearance in cereal crops following the ploughing-in of a plantation is not uncommon. Fortunately they are fairly readily controlled by cereal herbicides. As with potatoes, the removal of these weeds is desirable from the rotational point of view to discourage the persistence of diseases and pests of the crop. The problem of raspberry suckers as 'weeds' of raspberry plantations did not arise until herbicides began to replace cultivation as the normal method of weed control in the alleys between raspberry rows. Previously the frequency of cultivation required for weed control was more than sufficient to control suckers and to destroy their root systems. However, without regular cultivation, raspberry roots can spread unchecked from the crop rows into the alleys and establish a network of independent plants capable of producing large numbers of suckers every spring. Investigations by Lawson & Waister (1972) into various aspects of the withdrawal of soil cultivation in raspberries showed that the tractor-mounted chain flail was a more effective means of controlling sucker growth in the alleys than was shielded application of paraquat/diquat. The latter gave variable results even with repeated treatment and it was usually necessary to mow surviving suckers prior to fruit picking. As a guide to the efficient use of the flail and other cutting techniques, an examination was made of the effects of timing and frequency of removal of suckers on subsequent growth in uncultivated alleys and on cane and fruit production by the crop rows. Experience with paraquat/diquat suggested that purely contact herbicides which required several applications per season were not economic or practical alternatives to mechanical cutting. With effective translocated herbicides, however, there was the risk of herbicide movement along the root network to the crop row and hence of serious crop injury. As a possible method of avoiding this problem, discing along the sides of uncultivated raspberry rows was tested for its effect on the growth and fruit production of the crop. Its efficiency in preventing translocation was also examined in experiments on a range of potential herbicides.

METHOD AND MATERIALS

All experiments were laid out at Invergowrie on established raspberry plantations, grown on the stool system, which had received no soil cultivation since planting. Simazine or bromacil were applied for weed control in late March every year. Previous management for sucker control had involved repeated treatment with either the chain flail or paraquat/diquat between early May and mid-July. Rows were 185 cm apart, with canes planted 60-70 cm apart in the row. All experiments were laid out in randomised blocks with between three and six replicates depending on the number of treatments. Sucker removal treatments involved cutting to ground level with a sharp knife. Both cutting and spraying treatments were applied when 20% of suckers on appropriate plots reached the desired height and cut vegetation was returned to the plots after assessment. The alley was defined for experimental purposes as terminating 30 cm out from the row centre. In practice, since suckers do not normally grow in tractor wheelings, for reasons possibly associated with soil compaction (Soane, 1970), there was a clearly visible gap between the canes in the crop row and the suckers growing in the alley. Herbicides were applied to a band 1 m wide in the centre of the alleys by Oxford Precision Sprayer in 1000 l water/ha. Adjacent rows were shielded with polyethylene screens to avoid spray drift, so that any symptoms appearing in the row would be due to translocation via the roots. Discing treatments involved running a disc to a depth of 13-18 cm along both sides of the raspberry row 30 cm from the centre of the row. The disc, mounted on a tractor tool-bar was 41 cm in diameter with a 10 cm hub, slightly offset and left a slit 3-9 mm wide.

RESULTS

Expt. D11

Starting in 1968, cutting treatments were applied for three successive years to alleys of a plantation of cv. Malling Jewel planted in April 1964. Plots were 8.3 m long comprising two adjacent cropping rows plus shared guard rows, giving 3 alleys per plot. Treatments were applied to all alleys but records were taken only on the centre alley. Experimental treatments involved cutting suckers initially at 15, 30 or 45 cm height or just prior to fruit harvest. Plots first cut at 15 cm were cut twice more i.e. when regrowth reached 15 cm and again pre-harvest; plots first cut at 30 cm and 45 cm were cut again pre-harvest. The heights achieved by sucker regrowth at the final date of removal were remarkably consistent over the three years. Plots cut twice at 15 cm reached 12-15 cm again, while those cut at 30 and 45 cm reached 28-32 cm and 10-15 cm respectively. The dates of the second cut at 15 cm and the first cut at 45 cm coincided in each of the three years. Suckers left uncut until just before fruit harvest reached 90-120 cm height. Dates of first treatment varied slightly from year to year, but on average, suckers reached 15 cm in mid-May, 30 cm at the beginning of June and 45 cm in mid-June. Regardless of treatment, there was no further emergence of suckers after mid-July. Cane production and fruit yields in the crop rows were recorded for each of the three years (Table 1). No differences directly attributable to sucker management treatments were found. In 1968, plots cut at 45 cm produced less fruit than plots given other treatments. Numbers of canes tied-in on those plots prior to the start of the experiment were lower and this, rather than any effect of experimental treatment, is thought to have been largely responsible for the lower yield per plot.

Because of considerable natural variation in the sucker population in this experment, effects of treatments on numbers of suckers are presented after covariance on a uniformity assessment made in 1967 (Table 2). In consequence, plot totals as shown, do not always correspond to the sum of the individual components. In 1968 there were no significant differences in numbers of suckers removed at the first cut regardless of date of treatment. Cutting at 15, 30 and 45 cm height stimulated considerable further emergence. As a result, total numbers over the season on plots

Table 1
Expt.D11 - Cane & fruit records

Height of suckers at first cutting date (cm)	1968 Y	1968 N	1968 C	1969 Y	1969 N	1969 C	1970 Y	1970 N	1970 C	1968-70 Cum. yield
15	9.2	122	227	9.0	121	229	11.5	143	247	29.7
30	8.8	127	211	9.1	130	218	10.9	141	237	28.7
45	7.4	112	199	9.2	118	238	11.0	131	256	27.6
90-120 (Pre-pick)	9.1	125	225	8.9	115	235	11.0	144	233	29.0
S.E. mean ±	0.33	7.9	14.5	0.83	6.7	12.4	0.59	7.3	16.0	1.27

Y - Fruit yield in tonnes/ha
N - No. of canes tied in/plot
C - Yield of fruit (g)/cane

Table 2
Expt.D11 - No. of suckers per 10 m^2

Cutting frequency & dates	Height of tallest suckers at first cutting date (cm) 15		30		45		Pre-pick 90-120	S.E. mean ±
1968								
1st cut	230	(May 6)	279	(May 27)	295	(Jun.10)	220 (Jul.16)	30.1
2nd cut	204	(Jun.10)	156	(Jul.16)	92	(Jul.16)	-	
3rd cut	125	(Jul.16)	-		-		-	
Total	588**		437*		386		227	59.7
1969								
1st cut	152*	(May 20)	263	(Jun.3)	296	(Jun.18)	234 (Jul.17)	24.3
2nd cut	238	(Jun.18)	275	(Jul.17)	92	(Jul.17)	-	
3rd cut	203	(Jul.17)	-		-		-	
Total	593***		533***		390*		232	33.5
1970								
1st cut	204	(May 13)	247*	(Jun.3)	246*	(Jun.11)	150 (Jul.21)	25.3
2nd cut	210	(Jun.11)	124	(Jul. 21)	60	(Jul.21)	-	
3rd cut	91	(Jul.21)	-		-		-	
Total	505***		370***		307**		150	30.4

* / ** / *** significantly different from Pre-pick at the 5% / 1% / 0.1% levels

Table 3
Expt.D8 – Cane & fruit records

Annual Treatment	1970 Y	1970 N	1970 C	1971 Y	1971 N	1971 C	1972 Y	1972 N	1972 C	1973 Y	1973 N	1973 C	1974 Y	1974 N	1974 C	1970–74 Cum. yield
No discing	11.0	41	366	6.6	58	152	8.6	71	163	8.2	62	179	9.0	78	153	43.4
Disced once	10.9	43	347	7.4	62	159	10.1	81	167	8.6	73	163	9.8	85	156	46.8
Disced thrice	11.9	44	369	8.4	64	178	9.3	71	178	8.3	68	164	9.0	85	141	46.8
S.E. mean ±	0.74	3.3	18.7	0.45	2.0	9.4	0.49	5.2	9.3	0.39	5.3	16.2	0.84	4.9	14.5	2.45

Y – Fruit yield in tonnes/ha N – No. of canes tied in/plot C – yield of fruit (g)/cane

Table 4
Expt.K24 – Crop & sucker records

1973 Treatment	Fruit and cane records: 1973 Yield tonnes /ha.	1973 No. canes /plot	1973 Yield (g) /cane	1974 No. canes /plot	1974 % at tipping height	1974 Mean height(cm) untipped	Suckers/7.5m²: 1973 Jul.9 No.	1973 Jul.9 Mean height(cm)	1974 Jul.10 No.	1974 Jul.10 Mean height(cm)	1974/73 % Nos.
No discing	11.5	111	207	116	89	198	64	63	40	53	63
S.E. mean ±	0.29	0.2	5.3	5.9	1.9	2.4	8.1	2.4	4.1	3.9	4.3
Disced once	11.7	111	211	104	93	197	63	61	34	53	53
Disced twice	11.9	111	215	107	88	198	76	66	33	58	46*
Disced thrice	11.5	111	209	115	91	197	56	59	20*	42	33**
S.E. mean ±	0.41	0.3	7.5	8.3	2.7	3.4	11.5	3.4	5.8	5.5	6.1

* significantly different from No discing at the 5% level
** significantly different from No discing at the 1% level
*** significantly different from No discing at the 0.1% level

cut at 15, 30 and 45 cm were 2.6, 1.9 and 1.7 times higher respectively than on plots cut once pre-picking. In 1969, significantly fewer suckers appeared on plots cut 3 times in 1968 than on all the other treatments. Differences in numbers between the other treatments were not significant. Early cuts again stimulated considerable further emergence, particularly on plots cut at 15 cm. Total numbers on these plots were very similar to those recorded in 1968. In 1970, sucker numbers on plots cut only once were significantly lower than on the first cutting date of the 30 and 45 cm treatments. Differences between the 15, 30 and 45 cm treatments were not significant. Total numbers on treatments cut at 15, 30 and 45 cm were 3.4, 2.5 and 2.0 times higher respectively than on those cut once pre-harvest. Over the three years, there appeared to be little permanent variation in initial emergence of suckers as a result of frequency of cutting treatment and considerable uniformity in the immediate response to particular cutting treatments.

Expt. D8

To examine the effect on crop production of isolating suckers by severing root connections between row and alley, discing treatments were imposed in 1970 on a plantation of cv Malling Jewel planted in April 1968. Plots consisted of single rows, 7.3 m long, with uncultivated alleys between plots. Rows were either not disced, disced once at the end of March prior to sucker emergence, or disced then and twice more at monthly intervals. Suckers growing in the alleys were controlled by chain flail. Treatment was repeated every year from 1970 until 1974. Cane and fruit records (Table 3) showed no evidence of any adverse effect of discing either in individual years or cumulatively. The only visible effect of treatment was that a fringe of small suckers tended to appear on the row side of the disc slit.

Expt. K24

Discing treatments were also imposed in 1973 in a plantation of cv Glenclova planted in April 1969. In this experiment two-row plots with shared guard rows were used, to allow an assessment of the response of suckers growing in the alleys. Rows were either not disced, disced once (March 15) or three times (March 15, May 8, July 4). There were two undisced treatments per block. Treatment was not repeated in 1974. In 1973 and 1974, cutting of suckers in the alleys was delayed until just before fruit harvest, when records were taken from the centre alley of each plot. Fruit production in 1973 showed no adverse response to discing and the number and heights of new canes produced in 1973 and tied in for fruiting in March 1974 also showed no differences between treatments (Table 4). No further discing was carried out and 1974 yields were not recorded. However, records taken in 1973 and 1974 on suckers growing in the alleys showed that while neither mean height nor numbers were affected in the year of discing, numbers in 1974 on plots disced three times in the previous year were significantly lower than those on undisced plots. Numbers in 1974 as a percentage of those produced in 1973 showed a clear trend of reduction as the frequency of discing increased (Table 4). This difference was significant on plots disced two and three times compared with those receiving no discing in 1973.

Expt. D6

Three herbicides were applied in 1973 to suckers growing in the alleys of a plantation of cv Malling Jewel planted in April 1974. Treatment details are shown in Table 5. Plots consisted of single alleys 3.7 m long. Adjacent crop rows were disced on both sides on March 15. Herbicide treatments were applied on March 28, May 24, or on June 15. Paraquat was taken as the standard by which to assess treatment effects, its use pre-emergence being regarded as equivalent to an untreated control. No treatment applied pre-emergence caused any reduction in numbers or height of suckers (Table 5). Glyphosate applied at 15 cm height significantly reduced numbers, killing a high proportion of the treated vegetation and severely stunting the remainder. Some secondary emergence of apparently unaffected suckers occurred. Treatment at the later date killed fewer suckers, but treated vegetation remained stunted and malformed for the rest of the season. Paraquat applied post-emergence burned treated foliage but most suckers produced new foliage and continued to grow. Treatment at 45 cm checked growth sufficiently to reduce mean height in

Table 5
Expt.D6 - Sucker records/5m^2

Treatment Herbicide kg a.i./ha		Size	1973 Aug.28 No.	Mean height(cm)	1974 Jul.19 No.	Mean height(cm)	1974/73 % Nos.
Paraquat	1.1	0	52	89	43	90	81
		15	43	84	37	96	86
		45	58	65***	37	86	63
Glyphosate	2.2	0	58	101*	48	95	80
		15	23*	51***	33	91	149**
		45	31	26***	43	78	141**
Pronamide	2.2	0	61	87	56	95	95
		15	48	80	51	93	115
		45	64	58***	55	99	88
S.E. mean ±			9.1	3.6	11.2	5.0	14.9

0 - sprayed pre-emergence 15 - sprayed at 15cm high 45 - sprayed at 45cm high

* / ** / *** significantly different from Paraquat 0 at the 5% / 1% / 0.1% level

Table 6
Expt.A12 - Sucker records 1974

Treatment kg a.i./ac		No.suckers/2m^2 Apr. 24	Jun. 10	Mean sucker height(cm) May 14	May 30	Jul.2	Injury scores 0-10 May 14	May 30
Untreated		72	67	23	44	78	0	0
Paraquat	1.1	66	51*	14***	28***	58***	2.0	1.3
Glyphosate	2.2	72	62	12***	10***	10***	3.3	6.8
Pronamide	2.2	69	65	14***	29***	59***	0	0
Dinoseb	1.0	73	66	15***	27***	60**	2.3	1.3
Metribuzin	1.0	63	59	15***	30***	59***	2.5	0.8
Methazole	2.1	70	63	17***	29***	59***	2.5	1.8
Metoxuron	3.6	66	65	18***	34***	70	2.0	1.3
Phenmedipham	1.1	65	67	18***	34***	65*	2.3	1.3
Asulam	1.7	63	63	18***	33***	64**	1.5	1.3
Ioxynil	0.7	70	64	17***	30***	60**	3.0	1.8
Aminotriazole	2.2	69	52*	16***	13***	38***	3.3	6.5
S.E. mean ±		2.9	4.2	0.9	1.2	3.7		

* / ** / *** significantly different from Untreated at the 5% / 1% / 0.1% level

late August compared with control plots. Both post-emergence treatments with pronamide caused leaf rolling and checked growth. This effect was outgrown by the younger canes within two weeks, but height was permanently affected by treatment at 45 cm. Rows adjacent to treated alleys were inspected regularly for evidence of translocation into the crop. Only two or three fruiting canes and an occasional young row cane produced visible leaf symptoms of glyphosate over the whole experimental area. Within a few weeks these symptoms were no longer visible. No evidence of pronamide or paraquat was detected. These observations suggested that the discing treatment had been very effective. In 1974, no significant differences in numbers and mean heights of suckers were recorded. However, 1974 numbers taken as a percentage of those in 1973 showed that significant recovery had taken place on plots treated with glyphosate, although occasional suckers showed leaf symptoms early in the season.

Expt. A12

This experiment was carried out in 1974 on a plantation of cv Malling Jewel planted in April 1972. Details of herbicide treatments are given in Table 6. Plot size was 3.7 m in length of a single alley. Adjacent crop rows were disced on April 3 and herbicide treatments applied to the alleys on April 25 when the young suckers were 10 cm high. Suckers were counted on 2 fixed quadrats of 1 m^2 area just before treatment and again on June 10. Only paraquat and aminotriazole significantly reduced numbers (Table 6). Both aminotriazole and glyphosate caused very severe stunting but some secondary emergence of apparently normal suckers occurred in June. There was little further emergence after treatment with other herbicides. Pronamide caused leaf curling and a temporary check to growth; dinoseb (applied in oil) and paraquat burned treated foliage but most of the suckers produced new leaves and grew away again. All treatments except pronamide caused some degree of yellowing or burning of sucker foliage. In most cases this was temporary, but the check was sufficient to reduce sucker height significantly on all treated plots. Only on plots treated with metoxuron was there any indication of recovery by early July. Both glyphosate and aminotriazole produced visual evidence of translocation from treated alleys into adjacent crop rows. 2-4 fruiting canes out of a potential 30-40 per row and a similar number of young canes produced leaf symptoms, which were soon outgrown. Discing was therefore not quite as effective in preventing translocation as in Expt. D6.

DISCUSSION

Control by cutting The presence of suckers in the alleys in late spring and early summer obstructs access for routine spraying of pesticides, supplementary weed control and for the removal of between-stool suckers in the rows. If present beyond mid-July they can obstruct fruit picking. Practical usage has also shown that the chain flail is unable to cope effectively with dense vegetation above 60 cm height. Although suckers did not offer competition to the crop rows in these experiments provided they were finally removed prior to harvest, it is therefore desirable to remove them from the alleys while they are still relatively small. This means that several cuts will be needed every year since frequent cutting did not reduce the sucker population over the 3 year period. The response of suckers to the various cutting treatments was however consistent. Cutting repeatedly at 15 cm required 3 treatments per year. Cutting at 30 cm required a further cut pre-harvest at about the same height, while cutting at 45 cm produced some 15 cm of regrowth by harvest time. Delaying the first cut until suckers reach 45 cm is probably too late for efficient access, while cutting at 15 cm and only once again pre-harvest would restrict access later in the season. The best compromise would therefore appear to be the use of two passes commencing at 30 cm or three passes at 15 cm. Cultivars which emerge earlier in the spring and produce more vigorous growth than cv Malling Jewel may require more frequent cutting.

Effects of discing The lack of adverse effect of repeated discing along raspberry rows in these experiments is in agreement with earlier evidence (Lawson & Waister, 1972) that root disturbance by regular cultivation close to the rows did no harm and may even have been beneficial. The fringe of suckers produced on the row side of the slit in Expt. D8 and the reduction in the population of suckers in the alleys in the year following treatment in Expt. K24 suggest that regular discing not only severs previous root connections into the alleys, but may reduce further spread. It is doubtful however, if this can be used in any practical way by itself to reduce sucker populations. The disc was purely an experimental device and its depth of effective penetration was limited and variable. More effective results might be obtained with equipment of the type used for subsoiling. Nevertheless, the indications from both herbicide experiments in which it was used were that, despite the relatively shallow depth of root severence, discing was most effective in preventing translocation of herbicides from the alleys to the crop row. If the use of translocated herbicides proves to be an effective and economic means of controlling suckers, further development of this technique may be worthwhile.

Control by herbicides Of the herbicides tested, only glyphosate and aminotriazole caused sufficient stunting, malformation and death of suckers to prevent them impeding access for tractor operations. One pass with the flail just before harvest would have cleared surviving vegetation to allow access for pickers. Further investigation of dosage and timing is planned with these and other readily translocated herbicides. Paraquat and dinoseb in oil severely burned sucker foliage, but new leaves were produced and most of the suckers continued to grow. Pronamide caused temporary stunting of suckers but this was rapidly outgrown. Other herbicides caused only temporary chlorosis or slight burning of foliage and a check to growth. The rates used were those normally recommended for weed control and it is doubtful if increased dosage or repeated applications would have given effective control. However, all these herbicides checked suckers sufficiently to preclude their safe use as post-emergence treatments for weed control along the rows after the emergence of young canes. The fact that cutting stimulated further emergence of suckers indicates that numbers produced initially in the spring represented only a percentage of the potential population. Without cutting, emergence was generally complete by the time the suckers had reached 15 cm height. With the exception of glyphosate and aminotriazole, herbicide treatment did not stimulate further emergence and this may be a situation which can be exploited if effective contact herbicides can be found. One annual treatment made after full emergence might be sufficient, despite the reservoir of potential suckers beneath the soil surface. Combined control of suckers and weeds, particularly perennial weeds, by the directed application of foliar herbicides to raspberry alleys is a possible long-term objective. At present, however, the chain flail, despite the need for repeated treatment, will continue to be the simplest and most effective means of controlling raspberry suckers.

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PROBLEMS CAUSED BY WILD AND REGENERATING HOP PLANTS

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Summary Wild hop plants, including many males, are widely distributed in Britain, being particularly numerous in areas of commercial plantings. This creates difficulties for hop growers intending to eradicate male plants so as to adopt the foreign practice of producing 'seedless' cones.

Many hop seedlings appear when diseased or unwanted hop plantings are grubbed and there is much regeneration from debris remaining in the ground. This leads to the adulteration of varieties and to the carry-over of virus infection between successive plantings. It is essential to eliminate all regeneration growth when attempting to prevent the recurrence of nettlehead and related diseases by fallowing; a practice that facilitates the loss of virus from the nematode vectors in the soil.

Le houblon sauvage se trouve largement réparti dans les Iles Britanniques et particulièrement dans les zones à production commerciale. Ceci crée des difficultés pour ceux des producteurs de houblon désirant se passer de pieds mâles, adoptant ainsi la pratique étrangère de production de cones sans graine.

Quand des plantations de houblon maladiées ou par ailleurs indésirables sont arracheés, de nombreux semis de houblon apparaissent et il y a de plus croissance de nombreuses tiges à partir des debris restés dans le sol. Ceci conduit au mélange des variétés et à la contamination virale entre plantations successives. Il est particulièrement important d'éliminer les pousses issues des débris aussi rapidement que possible lors de la mise en jachère, afin d'éviter la réapparition du nettlehead ("tête d'ortie") et des maladies semblables. La mise en jachère est une pratique qui facilite la perte du virus par le nématode vecteur dans le sol.

INTRODUCTION

The hop (Humulus lupulus L., Cannabinaceae) is grown in many temperate countries to provide cones containing the alpha-acid resins required by the brewing industry. There were 16,735 acres of commercial plantings on 496 farms in England in 1973, when the crop totalled

10,280 tons, worth approximately £10 million. This represents approximately 9% of total world production, which is dominated by the U.S.A. and West Germany.

Growers in all regions encounter serious problems due to the occurrence of 'wild' and seedling hops and to regeneration from previous plantings. Such growth acts as a source of disease and the frequent appearance of seedlings and other 'rogues' leads to the adulteration of varieties. Moreover, the widespread distribution of male hop plants causes difficulties to English growers intending to follow foreign practice and grow seedless hops. Various aspects of these problems are now considered, with emphasis on the importance of regeneration growth in the epidemiology of nettlehead and related virus diseases.

THE DISTRIBUTION OF HOP IN THE BRITISH ISLES

Hop pollen occurs in peat deposits and the hop is listed in the current British flora as native and widely distributed in Europe and western Asia. It has been recorded in the Channel Islands, in 100 of the 114 vice-counties in Great Britain and in 23 of the 40 in Ireland (Clapham *et al.*, 1952).

The hop is a dioecious perennial with a similar habit of growth to bryony (*Bryonia dioica* Jacg.), *Convolvulus* spp. and clematis (*Clematis vitalba* L.). It is commonly found with these species and also elsewhere in hedgerows and thickets. Many of the plants occurring in these situations originate from commercial plantings that previously were much more numerous and more widely distributed than at present.

Hop growers often throw unwanted plants and debris into hedges or onto waste ground and male plants have sometimes been established in hedgerows to provide the few cuttings per acre required to accompany new plantings. Numerous 'wild' hop plants also develop from seed dislodged from the cones at harvest. Many other seeds are carried by birds or scattered by wind, especially when surplus hops or those on young plants are left unpicked. Clearly, there have been numerous opportunities for the hop to escape. Once plants are established in natural habitats they are extremely persistent, which accounts for their common occurrence, even in areas remote from present plantings.

HOP PLANTINGS IN BRITAIN

Hops have been used in brewing since the twelfth century and have been produced in Britain since the early sixteenth century. The acreage expanded rapidly and by 1870 hops were being grown in forty English counties, eight in Wales and five in Scotland as far north as Aberdeen (Burgess, 1964). However, cultivation in Wales and Scotland ceased in 1871 and 1874, respectively. The peak of 71,789 acres was reached in 1878, with a subsequent decrease in acreage due to better utilization of hops by brewers and to the introduction of improved varieties, cultural practices and control measures against pests and diseases.

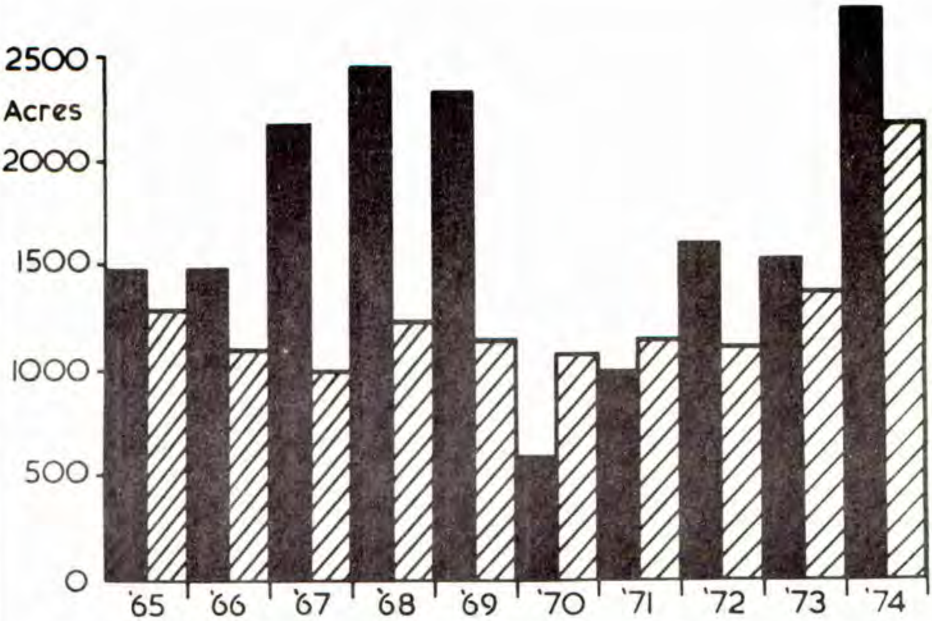

Fig. 1. Total hop acreages grubbed (solid) and planted (shaded) in England each winter from 1964-1965 to 1973-1974.

The acreage in England has fluctuated recently around 17,000 acres, restricted to Kent, Sussex, Herefordshire and Worcestershire, apart from a few plantings in Hampshire and Surrey and one in Berkshire. Annually there are only slight changes in total acreage, but there is much grubbing and replanting (Fig. 1). The spread of the progressive form of verticillium wilt disease in Kent and Sussex has necessitated a change from wilt-sensitive to wilt-tolerant varieties on many Weald farms. Other plantings, particularly in the West Midlands, have had to be grubbed and replaced because of nettlehead and/or split leaf blotch diseases. In all regions there has recently been a change to high-yielding varieties that has been encouraged by E.E.C. replanting grants. This accounts for the particularly great turnover in the winters of 1972-1973 and 1973-1974, when 16% of the entire acreage was replaced (Fig. 1).

HOP PLANTINGS AND REGENERATION

Mature hop plantings require expensive permanent posts and wirework to facilitate stringing and growers tend to replant existing areas rather than plant fresh sites. From the results of a questionnaire sent to all growers it was established that 88, 69 and 81% of all plantings in the winters of 1968-1969, 1969-1970 and 1972-1973, respectively, were on land with a recent history of hop cultivation. In all districts and in each winter, many grubbed sites were replanted immediately and few had been fallowed or used for other crops for more than 2 years (Fig. 2). The main reasons for this were the need to maintain output and the difficulty of using the sites for other crops without removing the poles.

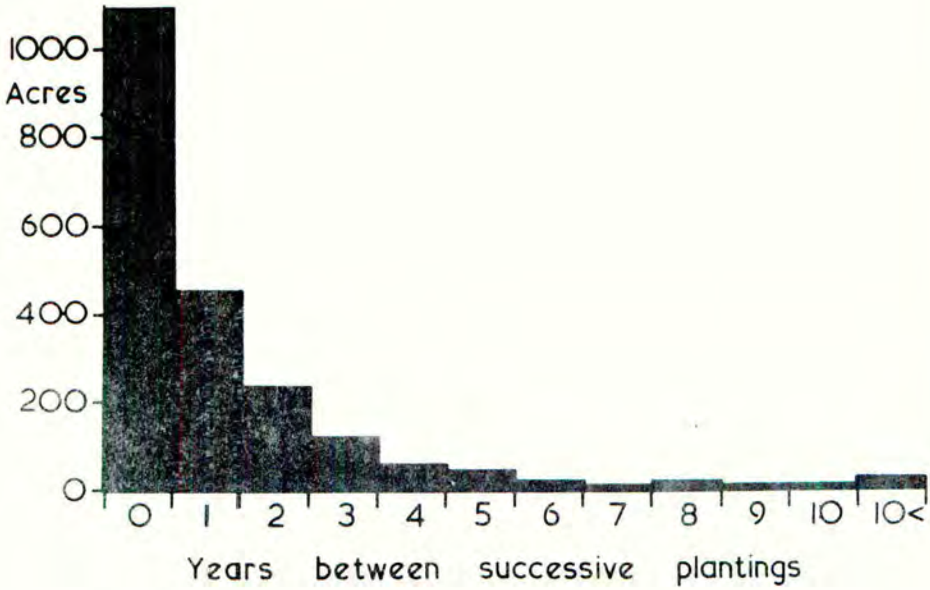

Fig. 2. The total acreage established at sites with a previous history of hop cultivation in relation to the nominal hop-free interval between plantings.

The repeated use of the same sites with little or no interval between successive plantings facilitates the growth of seedlings and regeneration from debris left in the ground at grubbing. Established hop plants have an extensive root system and a large perennial 'crown' of stem tissue at soil level. Severed roots do not produce adventitious shoots, but there is much growth from the buds on stem runners and from even quite small pieces of crown.

Deep ploughing, rotovation or lifters or diggers are used for grubbing and large pieces of debris are usually collected and dumped or burned. Inevitably many viable stem-pieces and seeds are left. It is seldom difficult to find seedlings and/or regeneration growth in the year after grubbing and these reappear in subsequent years unless special precautions are taken.

At an experimental site near Horsmonden, Kent, numerous hop plants occurred in a 1-acre plot 6 months after the original hills had been ploughed-out and removed. Young seedlings had survived,despite subsequent cultivation and an overall application of simazine. They were scattered over the whole area at an average density of 4,000 plants per acre. There was also abundant regeneration from stem runners and other debris (2,500 per acre).

Elsewhere, near Goudhurst, Kent, the highly characteristic five-lobed leaves of the variety Bullion were recognized on numerous plants that had regenerated within and between the rows of a later commercial planting var. Wye Challenger. This had occurred despite a 1-year bare fallow period maintained by repeated cultivation.

Similarly, at a farm near Hereford, where shoots of the original Fuggle variety were found intertwined with those of newly established plants of Wye Challenger. There had been no interval between grubbing and replanting,but several previous attempts had been made to identify and remove all regeneration growth.

Observations at a former hop garden near Headcorn, Kent, emphasize the persistence of the hop in seemingly uncongenial conditions. After several years of arable crops (including rape and cereals) there were numerous hop shoots climbing the stalks and within the stubble of a stand of wheat. Many of the plants had cones containing seeds and some of the plants were recently established seedlings.

The regeneration and persistence of hop plants at the various recorded sites was in no way exceptional and commercial growers regularly encounter similar difficulties. These are likely to increase with the increased use of simazine and non-cultivation techniques and with the current emphasis on immediate replanting.

PROBLEMS CAUSED BY WILD AND REGENERATING HOPS

1. The Adulteration of varieties

Hop plants are produced by propagating cuttings from cropping sites or from special sources. It is difficult to avoid the admixture of varieties and contamination by seedling 'rogues'. Such adulteration remains a long-standing problem of ever-increasing importance as the range of varieties, their health status and their reaction to pests and diseases become increasingly diverse.

Special 'A plus' certified stocks are raised in isolation outside the main hop-growing areas to decrease the risk of disease. For certification,all wild hop plants must be removed within 200 yards. The main reason for this is to decrease the amount of pollen in the locality and hence the number of seeds that reach the propagation areas.

The many propagators in the hop-growing areas cannot take these precautions, yet they provided approximately two thirds of all the plants used in recent years. Many cuttings are taken from (or grown on at) sites previously used for hop cultivation and where regeneration growth is likely to occur. It is possible to eliminate 'rogues' and seedlings with a highly characteristic leaf-form or stem pigmentation. However, this requires considerable skill and experience and in practice some varieties are virtually indistinguishable.

2. Unwanted pollination

Traditional British practice is to grow 'seeded' cones by interplanting females with a small proportion of males. Thus the numerous males amongst the wild plants around hop plantings are of little significance and no attempt has been made to locate or remove them. The situation is different in all other hop-growing countries, where determined efforts have been supported by legislation to eliminate all males and so produce 'seedless' cones. These are smaller and lighter than comparable seeded ones, but contain a higher proportion of alpha-acid resins.

The future policy in England is uncertain but growers in at least some districts are likely to dispense with males within the next few years. Several growers have already eradicated males from within and around their plantings in an attempt to grow seedless hops in experiments sponsored by the Hops Marketing Board. Other growers are still deciding future policy and those in Herefordshire and Worcestershire may be producing seedless hops by 1978. The distribution of males in and around these plantings is being recorded, pending a final decision and information on the best method of eliminating males and on the time of year when this is best done.

Males within hop plantings are usually labelled and they can be removed without major difficulty by the grower concerned, who can also eradicate wild hops elsewhere on the farm. It will be much more difficult, expensive and, in some instances, almost impossible to eliminate all wild hops from entire districts. Many plants occur deep within hedgerows, thickets or woodland and cannot be removed cheaply and without causing considerable damage unless a very selective herbicide is developed. Any large-scale operation over a wide area will require the good-will and voluntary co-operation of many other landowners and of the general public. Prohibitive legislation may be difficult to introduce and enforce.

The results of the H.M.B. trials (Table 1) emphasise the difficulties involved in producing cones with a seed content below the 2% dry weight standard customary in other E.E.C. countries. At the most isolated site, away from any other plantings, the average seed contents of two varieties was $<2\%$ in each of the two years. Elsewhere the results were much less satisfactory, although seed contents were invariably much lower than the 12 - 26% typical of seeded cones. The 2% tolerance was exceeded in half the growths sampled at sites outside the main hop-producing areas of Worcestershire and Kent. Similarly with all the growths sampled on adjacent farms down-wind from a major hop-growing district in Kent. These results indicate that except at very isolated sites there are only limited prospects of producing seedless hops from current varieties by local eradication.

Table 1

Number of growths with cones having an average seed content $<2\%$ dry matter*

Farms		1971	1972	1973	Total
Hants and Berks	(1)	-	2/2	3/3	5/5
Worcestershire	(1)	-	3/4	3/4	6/8
Kent: outlying areas[x]	(7)	6/21	20/27	10/30	36/78
Kent: other areas	(5)	-	0/17	0/16	0/33

* Expressed as a fraction of the total number of growths sampled in the H.M.B.-sponsored seedless hop trials on fourteen different farms involving a total of thirteen varieties.

[x] At some sites seed contents were influenced by pollen introduced for pollination trials on four farms in 1971 and on one in 1972 and 1973.

3. Virus sources

The recent changeover in hop varieties has coincided with an improvement in the health status of planting material. Clones of the latest Wye College varieties have been selected for their freedom from prunus necrotic ringspot virus (NRSV) that occurs throughout all older varieties (Thresh and Ormerod, 1974). There will be a further improvement with the introduction of clones derived from meristem-tips that have been freed from NRSV and two other viruses (hop mosaic and hop latent), that occur throughout the most important varieties (Adams, 1973).

Consequently, wild hops and those surviving from old plantings will be foci of infection for the spread of NRSV, hop latent and hop mosaic viruses to later and healthier plantings. At the Cranbrook and Hereford sites, for example, (p. 327) the regenerating shoots of the original varieties contained NRSV, whereas the replants were not infected initially.

Seedlings and regeneration growth from previous plantings are of special significance in the epidemiology of nettlehead and other important diseases associated with arabis mosaic virus (AMV). Infection is transmitted by a free-living 'dagger' nematode (_Xiphinema diversicaudatum_ Micol.) that has a wide host range and persists between successive hop plantings, even if the interval between them is a prolonged one of several years (Thresh and Pitcher, 1971).

Nettlehead tends to be prevalent alongside hedgerows and where hedges have been removed. The nematode vector thrives best in such undisturbed soil and the wild hop plants that occur commonly in hedgerows may have been the initial source of AMV. This virus is seed-borne and there is also a record of the seed-transmission of nettlehead.

AMV is only retained a few months by its vector and bare fallowing is effective in preventing the recurrence of infection at sites where disease occurred previously (McNamara et al., 1973). The success of this technique depends on using AMV-free planting material and on the efficiency with which debris remaining in the ground is eliminated before or soon after it begins to regenerate. Otherwise the nematodes remaining in the soil re-acquire virus and spread is resumed. This occurred at the Horsmonden and Cranbrook sites (p. 327), where some of the regenerating shoots showed symptoms of nettlehead and many contained AMV. The Headcorn record of hop plants in wheat suggests that virus can so persist for years and reinfect any subsequent hop plantings.

DISCUSSION

Outside the areas of commercial production the wild hop is a minor constituent of the local flora of no economic significance to growers, except at the few isolated sites (mainly in East Anglia) where 'A plus' certified planting material is produced. Within the main hop-producing areas the many wild male plants that occur will be an important hazard in any future attempts to produce seedless cones.

Meanwhile there is a well-known risk of varieties being adulterated by seedling 'rogues' or by regeneration growth from debris remaining after removing diseased or otherwise unwanted plants. The further risk of viruses being perpetuated in this way between successive plantings is now apparent. The problem is likely to become more acute with the general adoption of clones of improved health status. Growers have been warned of the hazards involved and especially when nettlehead sites are grubbed and replanted immediately. Current practices (p. 326) must be reassessed and it will be necessary to consider more carefully than hitherto the method, and efficiency of grubbing. A suitable herbicide is needed to prevent or eradicate regeneration growth and promote the rapid degeneration of stems and roots remaining in the soil. Thus it may be possible to increase the effectiveness of control by fallowing and perhaps decrease the minimum period required to avoid reinfection.

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NOTES

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WEEDS AS CROPS

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Summary There is a distinct possibility that a new agricultural technology may develop, based on growing mixed populations of non-crop species for the extraction of leaf protein to supplement human diets. The object of this paper is to alert agronomists and technologists to the interesting new weed-control problems that might result from such a development.

Résumé Il se peut bien qu'une nouvelle technologie agricole puisse se développer, basée sur la culture des populations mélangées des espèces non-agricoles, en vue de l'extraction des protéines des feuilles pour supplémenter les régimes alimentaires humaines. Le but de cet article est de signaler aux agronomes et aux technologues les nouveaux problèmes intéressants dans le domaine de la lutte contre les mauvaises herbes qui pouvaient résulter d'un tel développement.

Many world agriculturists and nutritionists are currently worried about the supply of edible protein, and a good deal of thought is being given to ways in which the supply might be supplemented, specially from new sources (Anon.1974).

One possible way of increasing the supply is by extracting edible protein from leaves by a process developed by N.W. Pirie at Rothamsted Experimental Station (Pirie, 1971), in which leaf material is washed and pulped, and the resulting protein solution separated from the fibrous residue by pressing. The solution is heated quickly to at least 70°C and the denatured protein filtered off, washed, and dried, or preserved by canning, pickling, salting or deep-freezing.

Useful amounts of protein have been extracted from many types of leaves by Pirie and his colleagues, including such readily available sources as waste leaves from peas, potatoes and sugar beet, but the present conclusion is that the highest yields could probably be obtained from leaves that are grown specially for the purpose, e.g. cereals (cut green), grass and clover.

There is little doubt that the resulting protein is nutritious, and that food technologists would be able to present it in forms which could win consumer acceptance. Apparently there are considerable technical difficulties in scaling up the method of extracting leaf proteins from the pilot stage to the full-scale industrial level, but these difficulties could presumably be overcome if there was a sufficient demand for leaf protein at economic prices.

The foregoing facts and beliefs must lead to the conclusion that growing crops for the extraction of leaf protein for human consumption is not just a pipe-dream, but may well become a reality at some time in the not-too-distant future.

It therefore behoves agronomists to study the technological problems that would be involved in such a type of cropping, so that the necessary information is available if (or more probably when) it is needed.

The first approach should probably be to study the potential of growing existing crop plants specially for leaf protein, because we already know those crops so well, and their husbandry is so highly developed that we can count on the herbage species and leafy vegetables to give heavy and reasonably regular yields of leaves.

However, most of the present-day crops were selected long ago, many by our neolithic ancestors, for reasons which are utterly irrelevant to the application of modern technology to growing crops for the extraction of leaf protein. It is therefore by no means obvious - at least to me - that the present range of crop plants has the maximum potential for future exotic systems of agriculture such as farming for extractable protein or, for that matter, for industrial alcohol, methane, hydrogen, cellulose or other products that could readily be produced from plants if changing circumstances put new and attractive price tags on such products.

Indeed, it is surprising how very few of the known species of plants are in fact grown as crops, and equally surprising how little effort is being made to see whether any of the multitude of species that we do not at present grow as crops would, in fact, meet new agro-technology requirements better than the present rather restricted range of regular crop plants.

In much of Britain we have a climate that is exceptionally favourable for the more or less continuous growth of a plant canopy, and there are few countries as green as ours, where growth is so rarely completely stopped by cold (in winter) or drought (in summer). For instance, it is a matter of common experience that roadsides and waste ground are nearly always covered by green plants, though not, of course, as a result of the growth of the same species throughout the year. Some species burgeon in early spring, long before grass starts to grow, whilst others keep growing well into the winter, after most crop plants have either died down (potatoes) or stopped growing (grass).

It has often been said that low temperatures are the curse of British agriculture and horticulture. We have plenty of light for most of the year, high humidities that reduce water stress, and frequent rain, but not enough heat. However, there are big differences in the response of different species to low temperatures. Some, such as groundsel (Senecio vulgaris) and chickweed (Stellaria media) are capable of germinating, growing, flowering and seeding, as every gardener knows, when it is too cold for most species to grow at all. It should therefore be possible to grow a mixture of species that would produce significant growth of leaves for a very large part of the year, in all but the coldest parts of Britain.

Pirie has always been somewhat scornful of "mixed weeds" as a source of leaf protein, but what is proposed is not a random selection of wild roadside plants, each surviving in its own ecological niche, but a carefully selected range of species in which some produce out-of-season leafage by drawing on underground reserves in storage organs, and others provide the main bulk of foliage when growing conditions are good, whilst a third group is able to take up the running in unfavourable weather conditions by producing leaves when it is too cold or too dry for their companion species. Thus all the components of the mixture would be chosen carefully for their ability to complement each other's responses to weather in such a way as to maximise leaf growth - e.g. by including species such as docks

(*Rumex obtusifolius*) and nettles (*Urtica dioica*) that recuperate rapidly after frequent cutting, as well as others that may take longer to regenerate, but whose leaves ultimately grow faster. The mixture would no doubt also contain nodulated species, to contribute significantly to the nitrogen status of the crop.

The success of such a system might well depend on our ability to keep the mixture "clean" by the use of selective herbicides, and the purpose of this short communication is to alert those concerned with the use of herbicides that they may one day be faced with a rather new type of problem, in which the aim will be to preserve the integrity of a mixed canopy of species that are currently unfamiliar as crop plants, and that may well include some that are now regarded as weeds.

Processing such crops may turn out to be difficult, but their agronomy will also be certain to present new problems. It is therefore not too early for us to be studying the potential of a wide range of candidate crops for inclusion in leaf protein mixtures, in the same way as the classic grass mixtures were studied and developed fifty years ago. It is interesting to speculate who might grow such crops - e.g. farmers, seeking new break crops, or horticulturists, who are skilled in dealing with unfamiliar and challenging problems. Whoever grows the crop, there seem likely to be formidable problems of weed control, which may one day present a new set of challenges to the younger members of this conference.

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NOTES

THE DECAY OF CEREAL STRAW AFTER SPRAYING WITH PARAQUAT AND GLYPHOSATE

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Summary The effect of paraquat (1.7 kg/ha) and glyphosate (3.4 kg/ha) on the decay of ^{14}C-labelled rye leaves incubating on the soil surface and of unlabelled barley straw, covered by a shallow layer of soil, was studied in the laboratory. Paraquat and glyphosate had no effect on the decay of rye leaves on the surface and glyphosate did not affect degradation of barley straw. However, paraquat significantly suppressed the decay of buried barley straw as measured by loss in weight, which was, after 16 weeks, between 40-55% of initial weight for control and only between 18-26% with paraquat. The addition of ammonium nitrate increased the extent of decay of barley straw treated with paraquat by about 17% but at the end of the experiment the weight loss was still smaller than for control straw.

INTRODUCTION

Increased utilisation of techniques of direct drilling and reduced cultivation has focussed attention on the need for rapid disposal of straw residues from cereals. This is necessary for successful re-seeding and establishment of a new crop which trash affects adversely, as shown by Squires and Elliott (1972) with respect to grasslands. Furthermore, a hazard may arise through the overwintering of cereal pathogens on straw residues. The decay of straw under normal conditions is a slow process and further delay in undesirable. Burning, which, so far, is the most extensively used means of disposal, may be restricted in future.

Herbicides can inhibit or stimulate cellulose decomposition in soil (see Weed Research Organization, Annotated Bibliographies nos. 58-64; reviewed also by Audus, 1970; Grossbard, 1974). Since cereal straw consists to a large extent of cellulose, herbicides might be expected to act in a similar way on straw to that on pure cellulose.

Specifically, it has been shown that paraquat (as 'Gramoxone W') influenced the colonisation of plant remains by various fungi among which were cellulolytic species. This herbicide exerts clear antifungal activity. This, however, is selective in as much as some fungi, such as the pathogen *Fusarium spp.*, are more resistant than saprophytes such as *Trichoderma viride* enhancing invasion of plant remains by the pathogen (Wilkinson and Lucas, 1969).

Grossbard *et al*. (1972) examined the decay of barley straw, sprayed in the field with paraquat and aminotriazole. The straw was allowed to decompose in the field, as well as in the laboratory under controlled environmental conditions. No significant effects were observed, possibly because of the considerable variability of material sprayed under field conditions. As the spray coverage in the field is imperfect the experiments were repeated with an improved method of spraying in the laboratory

(Grossbard and Wingfield, in press) using twice the field rate and comparing paraquat with glyphosate. The latter enhanced cellulose decomposition in soil in other work (Grossbard and Wingfield, unpublished).

To simulate in the laboratory the conditions that might occur in direct drilling situations, the decay of fragments of ^{14}C-labelled rye leaves, left to incubate on the soil surface, was studied. Tracer techniques allow observation of the fate of such plant remains with a minimum of disturbance (Grossbard, 1969). Incorporation by shallow cultivation was imitated by burying unlabelled barley straw in "Terylene" bags since insufficient labelled rye was available for the latter purpose.

It has been shown that the addition of a nitrogen source may accelerate the process of straw decay in the field (Scott, 1969). Thus an examination of the effect of the addition of ammonium nitrate on herbicide sprayed straw was included in this work.

METHOD AND MATERIALS

I Materials

1) Straw

a) Incubation on soil surface: fragments of rye leaves labelled with ^{14}C, 420 µmCi/g carbon, freeze-dried.

b) Burial in soil: barley straw grown on Begbroke Hill Farm, harvest 1972 and 1973; portions of stem about 5 cm long, each with one node.

2) Soil

From Boddington Barn Field, Begbroke Hill, pH 6.5, organic C 1.4%, total N 0.15%.

3) Herbicides

a) Paraquat as 'Gramoxone W' at 1.7 kg/ha.

b) Glyphosate as 'Roundup' at 3.4 kg/ha.

Both rates are equivalent to about twice the field dose.

II Methods

1) Incubation of ^{14}C-labelled rye leaves on the soil surface

Fragments of rye leaves were fixed on a Dexion frame and sprayed with either water or herbicide using a laboratory pot sprayer (Grossbard and Wingfield, in press). After drying, the leaves were placed on the surface of soil in plastic boxes. The soil moisture was adjusted, and then maintained throughout the experiment, to approximately field capacity. The boxes were covered with 'Melinex', a polyester film, which was perforated. The soil box was enclosed in a plastic container together with two specimen bottles with 1N NaOH to absorb CO_2 evolved from soil. The boxes were incubated in the dark at 23°C. After 2, 4, 8 and 16 weeks the NaOH was removed and replaced by fresh samples. Autoradiograms were prepared at the start of the experiment and repeated at the same time as the NaOH samples were removed (Grossbard, 1969). Radioactivity in the NaOH was determined by scintillation counting on a Beckman counter. The density of the autoradiographic images was measured on a Wooster micro densitometer*.

* Manufactured by Crystal Structures Ltd. 339 Cherry Hinton Road, Cambridge

2) Incubation of barley straw buried in soil

The straw was sprayed similarly to the rye leaves. Twenty stems in double 'Terylene' fine mesh bags were placed in seed boxes on soil of about 1.5 cm depth and covered with a layer of soil about 2.5 cm deep. Six bags were inserted in each of four replicate boxes per treatment, the moisture content adjusted, the boxes placed in sealed polythene bags and incubated at 23°C. At intervals of two weeks the large bags containing the soil boxes were aerated and the moisture content adjusted to its initial level, if necessary. After 4, 8 and 16 weeks two bags were removed for assessment. In the second experiment six replicate boxes had to be set up to accommodate a total of four bags for the increased incubation period of 32 weeks.

The content of each bag was weighed and the dry weight (at 80°C) determined on subsamples for the calculation of loss in weight. This was expressed as a percentage of the initial dry weight. Oxygen uptake was measured manometrically on other subsamples as a criterion for microbial activity.

3) Addition of ammonium nitrate to barley straw buried in soil

Whole stems of barley straw, as prepared previously, were sprayed 1) with water, 2) with water and ammonium nitrate at the rate of 12.3 kg/ha nitrogen, 3) with paraquat alone at 1.7 kg/ha and 4) with paraquat and ammonium nitrate. The straws were placed in bags, buried and treated as described above. Ammonium nitrate was sprayed on the soil for a second time 11 weeks after the start of the experiment. Loss in weight and oxygen uptake was measured as before.

4) Release of paraquat from barley straw

Whole stems of barley straw were sprayed with 1.7 kg/ha of paraquat and the amount retained determined on samples of about 5 g by the method described by Hance and McKone (1970). Whole stems were buried in soil in 'Terylene' bags as described previously. In addition, similar straws were split and placed on the surface of soil in seed trays and covered with a film of 'Melinex' to simulate the technique used with the radioactive rye leaves. Each box contained 7 g of straw. Both sets of soils were placed in the dark and maintained for 12 days at a temperature of 3-4° to avoid decomposition of the straw and the paraquat. Residues of the herbicide were then determined in these materials.

RESULTS

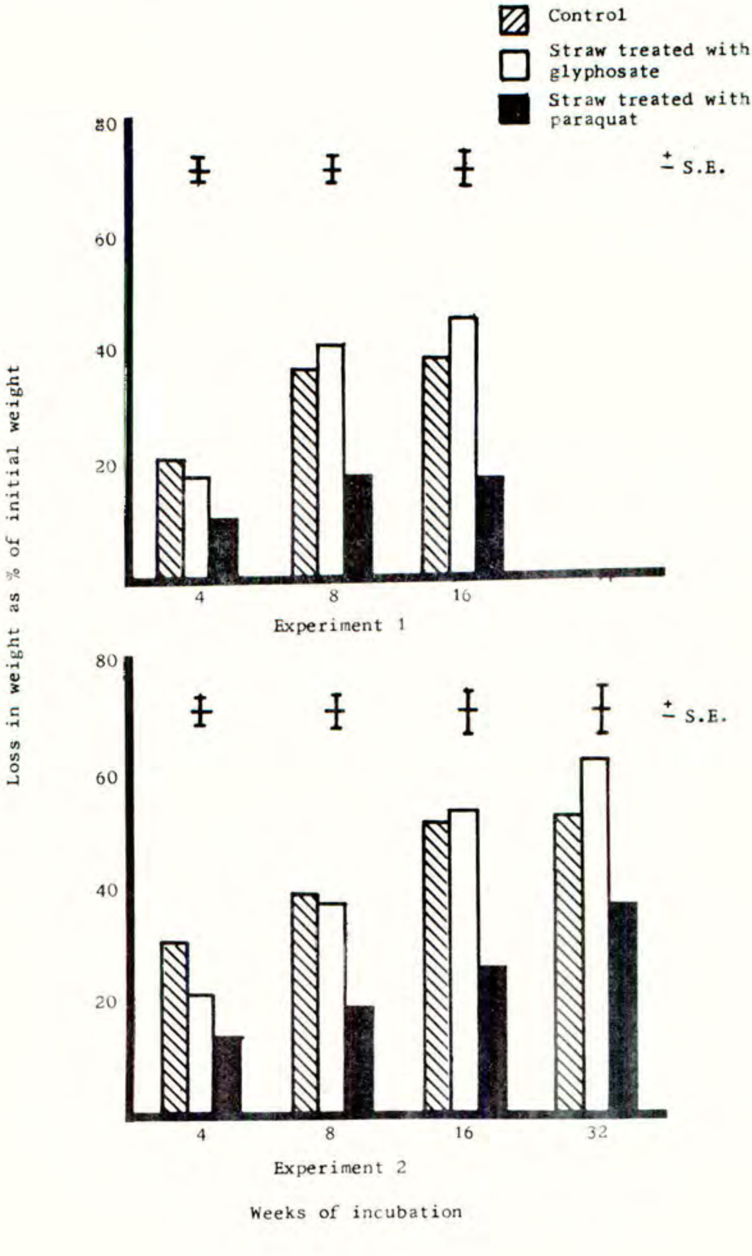
I Incubation of ^{14}C-labelled rye leaves on the soil surface

The radioactivity of the CO_2 evolved gives an estimate of the breakdown of the labelled rye leaves. In Table 1 it is expressed as a percentage of the first count carried out on NaOH samples after 2 weeks of incubation. No significant difference between the three treatments was found. There was a trend for the counts for paraquat treated leaves to be slightly greater than for the two other treatments indicating an enhancement of decay. Density readings of the autographic images of the remains of the rye leaves, gave an estimate of residual carbon at the same time as CO_2 output was monitored. These were similar in all treatments, again indicating that the herbicides did not inhibit the decay of the rye leaves incubating on the soil surface.

II Incubation of barley straw buried in soil

Paraquat significantly reduced the extent of decomposition of buried barley straw as compared with controls and glyphosate in both experiments, the effect persisting for at least 32 weeks (Fig. 1). In contrast, glyphosate had little effect,

Figure 1. Loss in weight of barley straw during incubation in soil



though in the second experiment a significant inhibition occurred once, during the first four weeks of incubation but a stimulation after 32 weeks. The data on O_2 uptake showed a similar response. Glyphosate caused an inhibition only at one occasion but in each case the extent was less than that due to paraquat.

Table 1

The radioactivity attributable to $^{14}CO_2$ evolved from soil containing ^{14}C-labelled rye leaves, sprayed with paraquat and glyphosate

Weeks of incubation	Water	Paraquat	Glyphosate	S.E. ±
	Disintegrations/min %*			
0-2	100	100	100	
2-4	35	38	38	6.56
4-8	7	9	7	1.53
8-12	4	5	4	0.42
12-16	2	3	2	0.25

* % of the first reading after two weeks of incubation

III The effect of the addition of ammonium nitrate

Though the supply of additional nitrogen accelerated the decay of untreated straw, the effect was small and did not persist (Table 2). Paraquat treated straw responded to a greater extent to the addition of ammonium nitrate than did the untreated straw. Nevertheless, at the end of the experiment the decay of the straw was still significantly lower than in controls on the basis of both loss in weight and uptake of oxygen.

Table 2

The influence of addition of ammonium nitrate on the decay of barley straw sprayed with paraquat

Treatments	Weight loss as % of initial weight, Weeks of incubation: 4		8		16	
	%	Δ≠	%	Δ≠	%	Δ≠
Water	22		38		51	
Water + NH_4NO_3	28	+ 6	38	0	48	- 3
Paraquat	10		17		20	
Paraquat + NH_4NO_3	16	+ 6	25	+ 8	37	+17
SED		2.01		2.47		2.25

≠ Difference from treatment with NH_4NO_3

IV Loss of paraquat from barley straw

Chemical determination of residues in straw after 12 days showed that paraquat had been lost from both types of straw. However, the amount lost from the whole straw in 'Terylene' bags and buried in soil was greater than that from the split straw placed on the surface, i.e. 71 and 42% of the initial amount, respectively.

DISCUSSION

The present work shows that glyphosate and paraquat have had no significantly adverse effects on the decay of labelled rye leaves incubating on the soil surface. However, the two herbicides exerted different influences on the decomposition of barley straw buried in soil. Glyphosate rarely delayed decay of barley straw. This agrees with other results of Grossbard and Wingfield (unpublished) that showed the degradation of pure cellulose in soil is not delayed by glyphosate; sometimes it is even enhanced. Though there was one instance of an inhibitory effect of glyphosate with barley straw this was smaller than that caused by paraquat. This herbicide, in contrast to glyphosate caused a persistent and marked inhibition of the decay of barley straw. This is in agreement with results on the decomposition of pure cellulose, calico (Grossbard, 1974) or cotton wool, but not with earlier work with barley straw sprayed in the field. However, even in this experiment a trend could be discerned towards an inhibition of decay when the straw was buried (Grossbard et al. 1972), though differences from control failed to reach statistical significance. In the present work the addition of ammonium nitrate reduced the adverse effect of paraquat but failed to eliminate it entirely.

The known antifungal action of paraquat probably explains, in part, the delaying effect on the degradation of straw. While, on one hand, this preserves for a longer period the availability of a substrate for overwintering of pathogens, on the other hand several fungi, responsible for cereal diseases, are susceptible to the action of paraquat. Examples are species of Septoria (Gareth-Jones and Williams, 1971).

The balance between advantage and disadvantage in the field situation will depend on the relevant importance of these two opposing factions and the possible differential in the minimal inhibitory concentration required for the two groups of fungi.

The differences in the action of paraquat on rye leaves, incubating on the surface, from that on barley straw buried in soil may be due not only to the difference in the two incubation systems but also to the substrates. The type of experimentation was not comparable because ^{14}C-labelled barley straw was not available for this work. Another contributory factor may have been a different pattern of adsorption of paraquat. Plant materials treated with paraquat can release this herbicide as shown by Damanakis et al. (1970) and confirmed with straw in this work. The amounts were, however, smaller with material pressed on the soil surface than with that buried in bags.

The release of paraquat from rye leaves has not been measured. In view of the closer contact between rye leaves on the soil surface, the clay content of the soil will adsorb more speedily any paraquat that may be released. The microflora on straw in bags may be exposed to paraquat for a longer time interval - before adsorption eventually takes place - than may be the case with rye leaves. This may explain, in part, the inhibition of decay of straws in bags buried in soil.

Whatever the causes of the marked differences in the action of paraquat on the decay of the two types of plant remains, the results illustrate that the delaying effect of paraquat is not necessarily a general phenomenon. There are conditions that obviate an inhibitory influence. Furthermore the decay of, for instance, pure cellulose (Grossbard et al., 1972) has been shown to be enhanced if the soil but not the cellulose was sprayed. It is, therefore, necessary to investigate and define environmental circumstances that lead in some instances to a delay in disposal of straw residues exposed to herbicides and in other cases give a contrary result. The difference in the behaviour between paraquat and glyphosate illustrates well the selective action of herbicides even in such a complex system as the decay of straw in soil.

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