PROCEEDINGS OF THE

FIFTH BRITISH WEED CONTROL CONFERENCE 1960

GRAND HOTEL, BRIGHTON
ENGLAND

NOVEMBER 8th, 9th and 10th, 1960

The Conference was organised by the British Weed Control Council. The Proceedings may be obtained from the Secretary, 95 Wigmore Street, London, W. 1.

55 shillings

EXPERIMENTS WITH SIMAZINE AND OTHER HERBICIDES IN SOFT FRUIT CROPS

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Summary: Three successive annual treatments with simazine at 1, 2 and 4 lb/ac had no adverse effect on raspberries. Results of band spraying different widths suggest that the tolerance of the crop does not depend on treatment of a narrow band only. Absence of serious injury on newly-planted raspberries following surface applications at 8 lb/ac and the occurrence of severe damage where this rate was placed 3 and 6 in. deep, suggest that the crop owes part of its tolerance to the retention of the herbicide near the soil surface. Simazine at 2 lb/ac gave excellent control of germinating weeds and this rate appears safe on established raspberries. Atrazine had no harmful effect on this crop, after treatment for one year at 4 lb/ac, but amino triazole at 4 and 8 lb/ac caused severe injury. Very promising results were also obtained with simazine and atrazine in blackcurrants and gooseberries.

INTRODUCTION

The chemistry and herbicidal properties of simazine and related herbicides have been described by Gysin and Knüsli (1957). Early trials with simazine in soft fruit crops have given very promising results. In Switzerland, no short term injury on raspberries or currants was caused by doses up to 5 kg/ha (Anon 1957). Good results were obtained by Wood and Sutherland (1960) in raspberry cane nurseries in Scotland, where 2 and 3 lb/ac kept ground virtually weed-free for over two months, whilst cane growth remained excellent. In Northern Ireland, applications of 1, 2, 4 and 8 lb/ac in a fruiting plantation of Malling Exploit raspberries caused no growth-check or reduction in yield (Robinson 1960). In England, rates of 2.5 and 5 lb/ac gave virtually complete weed control in blackcurrants and raspberries without causing any adverse effect (Anon 1960).

Work with simazine and other herbicides in raspberry, blackcurrant and gooseberry plantations was continued at Loughgall in 1959 and 1960.

METHODS AND MATERIALS

The experiments were conducted at the Horticultural Centre, on a medium-heavy loam soil. Treatments were applied with an Oxford Precision Sprayer in raspberries and with a knapsack sprayer in blackcurrants and gooseberries. Sprays were applied at 50 gal/ac and all rates of application are given in terms of active ingredient. Wettable powder formulations of simazine and atrazine were used. Except where otherwise stated, applications in raspberries were made as directed sprays to a band 3 ft wide, with the cane row at the centre. Similar treatments in blackcurrants were made to a 4 ft wide band, while in gooseberries, application was confined to an area of 1 sq yd at the base of each bush and the remainder of the area was cultivated mechanically. Treatments were arranged in randomised blocks, usually with four replications.

To obtain information on crop tolerance, higher doses than those needed to give good control were sometimes used. The main purpose of the trials in fruiting plantations was to study the effect of the herbicides on the crop and in most experiments the sprays were applied on hoed ground, the plots being kept clean by hoeing.

Weed counts in raspberries were made on 12 one foot square quadrats in each plot. This crop was grown on the hedge system and no thinning of young canes was done until the winter. Cane counts and measurements were made on all young canes in two two-yard lengths of row selected at random in each plot. In blackcurrants the vigour of each plot was determined by measuring a sample of one-year-old shoots on every bush as described by Freeman and Thompson (1960), while in gooseberries the maximum bush circumference was used.

RESULTS

Effect on fruit crops

Raspberries

In June 1958 simazine at 1, 2 and 4 lb/ac was compared with 2,4-DES at 6 lb/ac in a plantation of Malling Exploit in its first cropping year. These treatments were applied to the same plots in May 1959 and again in April 1960, All plots were hoed immediately prior to spraying. Throughout the three year period there was no significant difference ($P = 0.05$) between treatments in crop yield or cane vigour. A single application of simazine at 8 lb/ac in June 1958 also caused no crop reduction or plant injury in that or the two subsequent years.

In another experiment simazine was compared with atrazine and amino triazole* (activated) in a plantation of Malling Exploit raspberries in its third cropping year. The triazines were used at 4 lb/ac and amino triazole at 2, 4 and 8 lb/ac The sprays were applied on 5th February 1960 on unhoed plots.

Simazine had no apparent phytotoxic effect on fruiting canes or emerging suckers but slight marginal necrosis occurred on some leaves on suckers where atrazine had been used. This injury was temporary, however, and subsequent growth was normal. Amino triazole at 2 lb/ac caused no injury to sucker growth but leaf size on fruiting canes was reduced. 4 lb dose checked the growth of suckers and caused severe stunting of foliage on fruiting canes. Double this dose killed 70 per cent of fruiting canes and temporarily suppressed sucker growth. A number of basal buds produced shoots on injured suckers and, at the end of the season, the number of canes was significantly greater than on the control plot, but this was accompanied by a reduction in height. All rates of amino triazole caused leaf chlorosis on fruiting canes. In late March this was estimated as being 10, 30 and 90 per cent of the total leaf area for the 2, 4 and 8 lb doses respectively.

The effect of the herbicides on yield and cane vigour is shown in table I. Crop yield was significantly reduced by amino triazole at 4 and 8 lb/ac.

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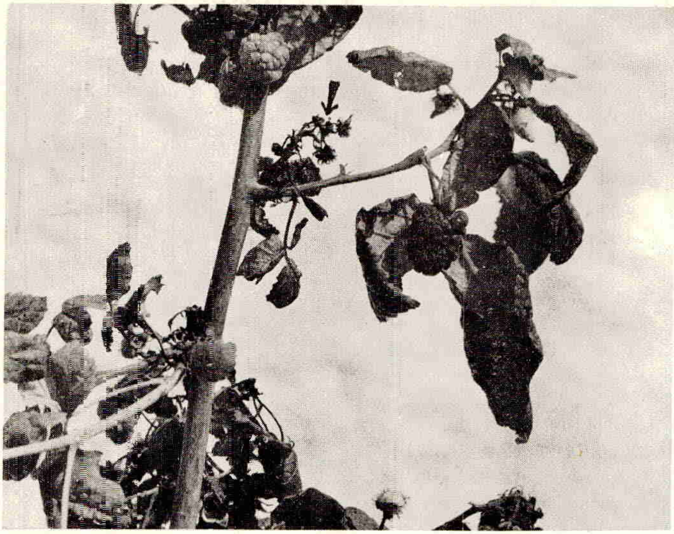
* Propriety product - Weedazol T - L



(a)

(b)

Effect of dalapon 3.7 lb/ac on Lloyd George raspberry (July 1960)

(a) Injured primary lateral following application in October 1959.
(b) Uninjured laterals following application in December 1959.

TABLE I. EFFECT OF HERBICIDES ON YIELD AND VIGOUR OF RASPBERRIES (FOUR REPLICATES)

Treatment lb/ac 5/2/60	Yield in lb/ 8 yd row	Young canes - August 1960	
		No. per row yard	Height, ft.
None	16.2	24.2	4.46
Amino triazole 2	15.7	25.9	4.43
" " 4	11.9+	24.5	4.45
" " 8	3.7*	29.5+	3.97
Atrazine 4	19.2	25.3	4.55
Simazine 4	17.5	28.0	4.60
S.E. of difference	± 2.0	± 2.1	± 0.42

* Differs significantly from control (P = 0.01)
\+ " " " " (P = 0.05)

In these experiments the spray was applied to a narrow band 3 ft wide containing the cane row, with an unsprayed alleyway 3 ft wide between the plots. To determine if absence of injury on simazine plots was due to the treatment of a narrow strip only, a rate of 4 lb/ac was applied to bands 1.5, 3 and 6 ft wide with the cane row at the centre. The raspberries, variety Malling Exploit in its second cropping year, were in rows 6 ft apart and the treatments were equivalent to rates of 1, 2 and 4 lb/ac of crop respectively. Simazine at 16 and 8 lb/ac was also applied to bands 1.5 and 3 ft wide respectively with the cane row at the centre. Both these treatments were equivalent to a rate of 4 lb/ac of crop. Spraying was carried out on 28th April 1959 and was repeated on the same plots on 26th April 1960. None of these treatments had any adverse effect on crop yield or cane vigour (P = 0.05).

It was then decided to investigate the possibility that the tolerance shown by raspberries to simazine might be influenced by the rotention of the herbicide at the soil surface. On 7th March 1960, simazine was placed in plots 6 yd x 2 ft at depths of 3 in., 6 in. and 12 in. from the soil surface by removing the soil to the desired depth and spraying the base of the trench while protecting the sides and ends with sacking. Canes of the variety Lloyd George were planted 2 ft apart, with the base of the cane about 6 in. deep, according to normal practice. To avoid disturbing the treated area, planting was carried out before or after spraying, according to the depth of the layer of herbicide. Canes were cut down to a height of 6 in. after planting.

Four replicates of the following treatments were carried out:-

1 Untreated control
2 Simazine at 8 lb/ac sprayed on soil surface after planting canes.
3 Simazine at 8 lb/ac placed 3 in. below soil surface when canes were partly planted.
4 Simazine at 8 lb/ac placed 6 in. below soil surface before canes were planted.

(78178)

5 Simazine at 8 lb/ac placed 12 in. below soil surface canes were planted.
6 Simazine at 8 lb/ac; rates of 2 lb/ac placed at 12 in. and 6 in. depths before planting canes, and at 3 in. depth and on soil surface after planting.

No injury appeared until mid-May when severe leaf necrosis was caused by treatment 4 and slight injury by treatment 3. By late June severe damage had resulted from treatments 3, 4 and 6, and new growth was significantly reduced ($P = 0.05$) on these plots as compared with treatments 1 and 5 (table II). Treatment 2 caused slight marginal and interveinal necrosis on the foliage of old canes and there was a small, although non-significant, reduction ($P = 0.05$) in new growth as compared with the hand-hoed control. Treatment 5 caused no injury throughout the season.

TABLE II. EFFECT OF SIMAZINE PLACEMENT ON GROWTH OF RASPBERRIES (FOUR REPLICATES)

Treatment 7/3/60	Depth of placement of simazine in. from soil surface	Total amount new growth (in ft) per 5 yards August 1960
1. Hoed	-	24.5
2. Simazine 8 lb/ac	0	19.8
3. "	3	11.4+
4. "	6	11.9+
5. "	12	27.2
6. "	2 lb/ ac at 0 in., 3 in., 6 in. and 12 in.	11.2+

S.E. of difference ± 4.4

+ Differs significantly from control. ($P = 0.05$)

Blackcurrants

In July 1959 an experiment was started on blackcurrants to compare annual applications of simazine and atrazine at 2 and 4 lb/ac. A mixture of simazine 1 lb plus atrazine 1 lb/ac was also included. Each plot contained six bushes and treatments were replicated eight times - twice on each of the four varieties, Cotswold Cross, Mendip Cross, Goliath and Wellington XXX. The spray was applied on 27th July 1959 on ground which had been unhoed since May. In October weed growth was severe on the unsprayed plots and the entire area was hoed then and again in March 1960.

In 1960 there was no significant difference between treatments in the crop yield as shown in table III. During 1960, a slightly greater amount of one-year-old wood was produced on sprayed plots than on the control, and the increase was significant ($P = 0.05$) where atrazine was used at 4 lb/ac.

TABLE III. EFFECT OF SIMAZINE AND ATRAZINE ON YIELD AND VIGOUR OF BLACKCURRENTS

(eight replicates)

Treatment lb/ac 27/7/59	Yield (in lb) per 5 bushes July 1960	Amount of 1 year-old wood (in ft) per bush September 1960
None	29.2	59.2
Simazine 2	32.1	65.8
" 4	31.7	75.1
Atrazine 2	33.9	75.4
" 4	29.6	76.4+
Simazine 1 plus atrazine 1	29.0	73.9
S.E. of difference	±2.7	±8.1

+ Differs significantly from control (P = 0.05)

Gooseberries

A long-term experiment on the effect of simazine and atrazine on gooseberries was also started in 1959. These herbicides were applied on the 30th September at 2 lb/ac. Treatments were replicated four times and plots contained three bushes of each of the following varieties, Lancashire Lad, Leveller and Whinham's Industry. The bushes were eight years old and were planted 6 ft apart in each direction. During 1960 the treatments caused no reduction in yield or check to growth on any variety.

Effect on weeds

In most cases simazine and atrazine were applied to ground which had been recently hoed, but in some experiments established weeds were sprayed.

The most prevalent weeds in the experimental area were *Poa annua*, *Holcus lanatus*, *Agrostis stolonifera*, *Stellaria media* and *Senecio vulgaris*, while *Atriplex patula*, *Polygonum aviculare* and *P. persicaria* were present occasionally. All these species were controlled on recently hoed ground for at least two months by either herbicide at 2 lb/ac. Application of simazine at 1 lb/ac resulted in a substantial reduction in number of most species, but *Polygonum spp.* and *Atriplex patula* were not always effectively controlled.

In the year following treatment, fewer weeds were usually present on plots sprayed with simazine than on hand-hoed plots. This is probably due to a reduction in the seeding of the weeds but a residual effect of the herbicide may be partly responsible. Table IV shows the reduction in weeds in 1960, on plots sprayed with simazine and 2,4-DES in 1958 and 1959. The weed count was made ten months after the second application. A similar reduction in weeds was also observed a year after treatment with atrazine.

TABLE IV. EFFECT OF SIMAZINE AND 2,4-DES ON WEEDS, TEN MONTHS AFTER TREATMENT.

(four replicates)

Treatment lb/ac 16/6/58 and 25/5/59	Grass per sq yd 15/3/60		Broad leaved weeds sq yd 15/3/60	
	Actual count	Sq root	Actual count	sq root
Control	18.6	4.25	17.7	4.17
Simazine 1	8.9	2.82	9.7	3.05*
" 2	6.1	2.32 +	5.6	2.33*
" 4	5.6	2.23*	3.6	1.87*
2,4-DES 6	15.4	3.88	15.4	3.90
S.E. of difference (transformed data)		± 0.68		±0.34

* Differs significantly from control (P = 0.01)
\+ " " " " (P = 0.05)

In the raspberry experiment in which amino triazole was compared with simazine and atrazine, the dominant weeds were young established plants of *Holcus lanatus*, *Agrostis stolonifera*, *Poa trivialis* and *P. annua*. Simazine and atrazine at 4 lb and amino triazole at 4 and 8 lb/ac gave a complete kill. Control was also good with amino triazole at 2 lb/ac but some plants of *Agrostis stolonifera* and *Poa trivialis* were only checked.

Stellaria media, the dominant weed in the gooseberry experiment, was about 3 in. high and formed a complete ground cover at the time of spraying. This species was killed by atrazine in two weeks and by simazine in about a month and sprayed plots remained weed-free during the winter. Weeds on the control plots were killed back by a routine spray of tar oil in January and hand-hoeing was not necessary until June. The plantation was cross-cultivated twice with a rotary hoe between March and June leaving only an area of one sq yd undisturbed at the base of each bush. On 1st June a weed count was made on the uncultivated area and the time required for hand-hoeing the weeds at the base of the bushes was recorded for each plot. The control of weeds in the sprayed plots was still evident, even after this hoeing, and hoeing times were again recorded on 27th July. The results in table V indicate the excellent control of grass (mainly *Poa annua*) and broad leaved weeds (mainly *Stellaria media*) by both simazine and atrazine. As a result of treatment on 30th September the time required for hand-hoeing sprayed plots on two occasions was significantly reduced (P = 0.01) compared with the untreated control.

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A PROGRESS REPORT OF TRIALS WITH SIMAZINE AND MONURON ON SOME FRUIT PLANTS

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Summary: Persistent herbicides have especial promise for use in perennial crops. Simazine at 2½ and 5 lb/ac and monuron at 5 and 10 lb/ac have been applied for two seasons to black currants and raspberries and for one season to a range of apples and pears at East Malling Research Station, Kent. The plants treated with simazine all appear perfectly normal and have shown no effects on vigour or yield. Monuron at the higher dose has proved too damaging for repeated use on the soft fruit crops whilst at the lower dose also it has adversely affected their growth or cropping. It is concluded from these preliminary results that simazine is very promising for use in fruit crops.

INTRODUCTION

Whilst some herbicides have been of use for particular weed problems which are of importance in fruit growing, it was only with the development of very persistent total weedkillers (initially for weed control on industrial sites and waste ground) that it became feasible to take advantage of the perennial nature of fruit crops by using herbicides which would give a long period of weed control. It would be possible to examine the effects of chemicals on the crop plants when used at rates expected to control an established stand of weeds, with possible residual effects for several years, or to use rates expected to control weeds for not more than twelve months, when applied to clean ground. For the present investigation the latter approach was chosen.

The two herbicides selected for trial are simazine and monuron. Simazine is one of a group of triazine derivatives which were described at the Third British Weed Control Conference (Gysin and Knusli, 1957). There are many reports of the use of simazine under apple trees. In Germany no harmful effects were found from autumn applications of 4 kg/ha on 2 or 4 year old apples (Karnatz, 1959), whilst rates of up to 10 kg/ha were reported to be promising (Loewel and Mohs, 1958). From Belgium it is reported that 1 kg/ha applied in the spring after planting and again the following year did not harm the apple trees, whilst growth was checked by 2½ kg/ha (Detroux et al., 1957). It is also reported that in a one year trial pear trees were not injured by 5 kg/ha (Dermine, 1959). In black currants 5 kg/ha was found to be promising (Karnatz, 1959), although the same author reports damage to black currants elsewhere, whilst in raspberries 4 kg/ha (Slaats et al., 1959) and two annual applications of 5 kg/ha (Gast, 1958) gave no injury.

Monuron was discovered in U.S.A. (Bucha and Todd, 1951). In a range of experiments on a total of 150 apple trees for up to 4 years no damage was seen from 5 or 10 lb/ac (Holm et al., 1959), and there is another report of 8 lb/ac having no effect on apples (Schubert and Amato, 1957). However, one year old trees have been damaged by 8 kg/ha (Detroux et al., 1957), whilst half this rate has injured older shallowly rooted trees (Jaivenos, 1958).

METHODS AND MATERIALS

The crops chosen for this work are raspberries, black currants, apples and pears. The raspberries used are a plot of the variety Norfolk Giant, planted in January 1957, and the herbicides were first applied in November 1958. The black currants are of the variety Westwick Choice, planted in 1956 and cut down so that they carried their first small crop in 1958, the treatments first being applied in November 1958. Both of these trials are laid out in randomised blocks, the unit plot for raspberries being a row 26 ft long, the rows being 7 ft 6 in. apart, and for black currants 4 bushes 5 ft apart, the distance between the rows being 8 ft. There are 7 replicates on the currants and 8 on the raspberries. The apples and pears are combined in one trial, having 6 replicates. The unit plot consists of one tree each of Worcester / M.VII, Cox / M.II, Cox / M.VII, Cox / M.IX and Conference / Quince A, planted in November 1958, and also Conference / Quince A planted in November 1959, the trees being 5 ft apart in rows 8 ft 6 in. apart. In all cases there are guard plants between plots in the same row, but no internal guard rows as the treatments are applied in a band 3 ft 6 in. wide.

The three trials are adjacent to one another on a deep, well drained, sandy loam of the Barming Series (Furneaux, 1954), at a height of about 150 ft above sea level. The pH is between 6.0 and 6.5. The alleys between the plots have been cultivated as required, whilst the treated strips have been hoed as soon as there was weed growth on the control plots, using shallow-acting horizontal bladed hoes to give a minimum of soil disturbance.

The herbicides applied are simazine as a 50 per cent wettable powder ('Weedex') and monuron as an 80 per cent wettable powder ('Telvar W'). Simazine is applied at 2½ and 5 lb/ac, monuron at 5 and 10 lb/ac, active ingredient, to weed-free ground in November. Applications have been made with a bucket pump delivering large droplets at a pressure of 50 psi, at 200 gal/ac.

RESULTS

On Westwick Choice black currants (Table I)

TABLE I. EFFECTS OF SIMAZINE AND MONURON ON BLACK CURRANTS

Treatment (lb/ac)	Shoot growth 1959 (mean/plot (cm))	Mean height/ bush (Aug. 1960 (cm))	Yield 1959 (lb/plot)	Yield 1960 (lb/plot)
Monuron 10	--^{x}	--	4.2^{xxx}	--
Monuron 5	6038	160	19.4^{xxx}	8.4^{xxx}
Simazine 5	7549	168	28.1	12.4
Simazine 2½	7983	165	26.1	12.0
Control	7394	162	25.9	12.6
S.D.	1331.8	N.S.	3.7	2.6

xxx - difference from control significant at 0.001 level
x - difference from control significant at 0.05 level

Monuron at 10 lb/ac killed 7 bushes during the summer after the first application, and the remainder showed severe leaf injury followed by death of shoots. The first symptom was marginal chlorosis. This gradually extended interveinally and was followed by necrosis and death of the leaves and then the shoots. At 5 lb/ac there was less extensive leaf injury, but the total shoot growth during 1959 was reduced. As a result of the severe damage caused by 10 lb/ac of monuron the yield was reduced by 84 per cent. 5 lb also gave a highly significant reduction. In the spring of 1960 approximately 70 per cent of the blossoms were killed by frost, resulting in an overall crop reduction of 55 per cent on the previous year, but there was again a highly significant reduction in yield. As an indication of growth in 1960 the heights of the bushes were measured in August and showed no significant differences. Because of the serious damage caused by monuron at 10 lb/ac this treatment was not repeated in November 1959. During 1960 the surviving bushes made reasonably good growth but showed leaf injury similar to that on bushes that received 5 lb/ac.

Simazine had no significant effect on the growth or yield of Westwick Choice. No symptoms of injury were seen on the leaves and the bushes appeared perfectly normal in every respect.

On Norfolk Giant raspberry (Table II)

TABLE II. EFFECTS OF SIMAZINE AND MONURON ON RASPBERRIES

Treatment (lb/ac)	No. of canes/plot 1959	No. of canes/plot 1960	Yield 1959 (lb) mean/plot x	Yield 1960 (lb) mean/plot x
Monuron 10	120	112 xxx	40.7 ≠	34.1 xxx
Monuron 5	134	157 xxx	43.0	58.8
Simazine 5	141	175	44.1	61.3
Simazine 2½	135	170	42.8	60.2
Control	142	178	45.7	60.7
S.D.	N.S.	20.2	3.3	5.9

xxx - difference significant at 0.001 level
≠ - difference nearly significant ($p < 0.1$)
x - adjusted according to 1958 yield

On the plots treated with 10 lb/ac monuron leaf injury was seen in May 1959, occurring on the leaves of the laterals on the fruiting cane but not on the new cane. The symptoms were similar to those described above on the black currants. There was a reduction in yield from this treatment which was nearly significant. The plots receiving 10 lb/ac monuron also produced the least number of canes during 1959, but the difference is not significant. During the following year there were very severe leaf symptoms on these plots, with highly significant reductions in the vigour of the canes and in the yield. In 1960 some leaf injury was seen on the plots receiving 5 lb of monuron, equivalent to that shown in the previous year by the plots receiving double the rate, when the 5 lb plots had shown no injury. The crop was not affected, but there was a reduction in the number of canes produced.

As with the black currants, the simazine treatments did not affect growth or cropping, the canes appearing perfectly normal in all respects.

On apples and pears

In the single season for which records are available leaf injury has been seen on only one tree, a 2 year old Conference pear which received 10 lb/ac monuron. The leaves of this tree showed very marked marginal chlorosis, but this did not extend interveinally. Shoot growth records are not yet available, but no differences are apparent and all other trees are growing normally.

On Weeds (Table III)

TABLE III. PERCENTAGE WEED COVER

Treatment lb/ac	Black currants June 1960	Black currants Sept. 1960	Raspberries June 1960	Raspberries Sept. 1960	Apples and pears June 1960	Apples and pears Sept. 1960
Monuron 10	(6)	(48)	0	0	0	0
Monuron 5	1	8	0	0	3	7
Simazine 5	1	3	0	0	3	3
Simazine 2½	3	3	0	0	3	5
Control	16	43	20	54	23	87

Note:- Convolvulus arvensis has been excluded from these figures.

Visual estimates of the percentage of the plot area covered by weeds have been recorded prior to each hoeing. During April 1959 there was much germination of Senecio vulgaris in the black currant trial amounting to 78 plants per square foot on the control plots. On the monuron plots the S. vulgaris continued to develop until hoed. During 1960 the monuron plots did not develop this great cover of groundsel even though the 10 lb/ac applications had not been repeated. Apart from this the 5 lb monuron and the simazine treatments all gave excellent weed control, except that during August each year Convolvulus arvensis developed on certain plots and appeared to be completely unaffected by simazine. The main weeds occurring on the control plots have been Capsella bursa-pastoris, Chenopodium album, Matricaria spp., Poa annua, Senecio vulgaris, Stellaria media, Veronica hederifolia, V. persica and Urtica urens.

DISCUSSION

Monuron at 10 lb/ac had such severe effects that this treatment had to be discontinued after one year on black currants and two years on raspberries; further, it is the only treatment to have shown any damage on the tree fruit, causing leaf injury to one pear tree. At 5 lb/ac monuron has given significant reductions in the growth and yield of black currants, whilst on raspberries it reduced the amount of new cane produced in 1960. Besides these adverse effects of monuron on the fruit plants, Senecio vulgaris, one of the most abundant annual weeds, showed considerable resistance to the herbicide even at 10 lb/ac. The increase in damage to the raspberries after the second application indicates that monuron may be accumulating in the soil, but bio-assays are necessary to confirm this.

It is, however, the results obtained with simazine that are of most interest. In no case has any effect on the growth or cropping been shown, although for the raspberries a difference in yield of 7 per cent (p 0.1) in 1959 and 10 per cent (p=0.001) in 1960 would have been significant.

A difference in yield of 14 per cent was significant (p=0.001) for the black currants in 1959, but in 1960 nearly three quarters of the blossoms were killed by frost, and a difference of 20 per cent was needed for significance at the same level in that year.

Thus monuron, even at the lower dose of 5 lb/ac has adversely affected black currants and raspberries, whilst at 10 lb some damage has been seen to a Conference pear during the first season after application. So far simazine, on the other hand, has had no adverse effects on any of these crops and appears to be an extremely promising herbicide for use in fruit crops. It must be emphasised that this preliminary report covers only two seasons for the small fruits and one for the top fruits. The experiments must clearly be continued for a number of years, and further investigations are needed on the persistence of simazine in the soil and of whether the crops are inherently resistant or whether the herbicide does not reach them in sufficient quantity to cause damage.

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EFFECTS OF THE USE OF HERBICIDES ON THE GROWTH, CROPPING AND WEED FLORA OF RASPBERRY PLANTATIONS: A PROGRESS REPORT

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Summary: Two statistically-designed field experiments with raspberries have received chemical weedkiller treatments in spring for three and two years respectively. Ine one, planted with the Norfolk Giant variety, the herbicides being used are mixtures of propham with 2,4-DES and with fenuron, of fenuron with 2,4-DES and of TCA with dinoseb. In the other, planted with Lloyd George, they are simazine, monuron and mixtures of 2,4-DES with propham and with fenuron. Fruit yields, cane growth and weed populations are recorded. The mixture of TCA (18.6 lb/ac in 1958 and 1959, reduced to 10 lb/ac in 1960) with dinoseb (2.8 lb/ac) has injured young stems and foliage in spring and depressed fruit yield and new cane production. Simazine (2.5 lb/ac) has apparently given good results but the increases of growth and yield associated with it are below significance level. Monuron (3.5 lb/ac) has given good weed control but caused some crop injury. These experiments remain in progress.

INTRODUCTION

Labour costs for soil cultivation are one of the larger items of expenditure in commercial raspberry growing, exceeded usually only by the cost of picking. Cultivations are necessary for the removal of surplus sucker canes as well as of weeds, and normally consist of hand-hoeing along the rows and harrowing and rotary cultivation of the alleyways. There is now an increasing interest, however, in the possible use of chemical herbicides, both to prevent the growth of annual weeds in clean plantations and to suppress perennial weeds where these are present.

This paper reports the progress of two field experiments in which chemical weedkillers are being used in combination with, and partly as substitutes for, normal mechanical cultivations. The objectives are to suppress weeds and reduce the amount of cultivation required, whilst at the same time measuring the effects of the treatments on the growth, yield and fruit quality of the crop. Both experiments will be continued for approximately the normal life of commercial plantations. Both are established at Mylnefield on medium loam land, largely free from perennial weeds but productive of a large flora of annuals, including Chenopodium album, Stellaria media, Senecio vulgaris, Poa annua, Fumaria officinalis, Viola tricolor, Veronica hederifolia. V. persica, Polygonum aviculare and P. convolvulus.

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METHODS AND MATERIALS

In experiment A, chemical weedkillers were first applied in spring 1958 to a 2-year-old plantation of the variety Norfolk Giant in which six former experimental treatments (dates of lifting of planting material from the nursery) were no longer of significant effect. The new treatments, arranged orthogonally in relation to the former ones within a 6 x 6 latin square design, were as follows:

(a) TCA (18.6 lb) + dinoseb-amine (2.8 lb)

(b) Propham (5.0 lb) + 2,4-DES (3.6 lb)

(c) Propham (5.0 lb) + fenuron (0.5 lb)

(d) 2,4-DES (3.6 lb) + fenuron (0.5 lb)

(e) Control (normal cultivation)

The unit plots are single rows 10 yd long, containing 12 stools, and the distance between the rows is 6 ft. In the new design the control treatment is allocated to 12 plots and each of the others to 6.

In 1958 the weedkillers were applied (already mixed) under dry, sunny conditions on 13 May, shortly after the completion of spring cultivations. They were sprayed in bands 3 ft wide alongside the rows, so that the whole soil surface between adjacent sprayed plots was treated. The control plots had to be hoed in mid-June. In 1959 the same treatments were applied on 9 April, again to freshly-cultivated, clean ground. All plots except those of treatment (a) were hoed on 16 June, and the appropriate mixtures were re-applied to those of (b), (c) and (d) on 20 June. The sprays this time were confined to bands 2 ft wide along each side of the rows. In 1960 the entire plantation was sprayed on 4 March with 8 per cent tar oil winter wash to destroy overwintered weeds, and treatments (a) - (d) (with the TCA in treatment (a) reduced to 10 lb) were then re-applied on 22 April after light cultivation. The sprays this time were confined to bands only 15 in. wide alongside the rows. Hand-hoeing between the stools was done on the control plots on 10 May and throughout the experiment on 23 May and 1 July, the May hoeing being mainly for sucker removal. The alleyways were rotavated with those of other plantations in the same field.

Experiment B was specially planted in spring 1959 to compare four herbicide treatments with a mechanical cultivation system in which the hoeing along the rows is done as far as possible with Dutch hoes, instead of the usual draw hoes. The variety is Lloyd George. The design is of six randomised blocks, with unit plots consisting of pairs of recorded rows 10 yd long, alternating with single guard rows. Multiple-row plots of this kind are preferable for herbicide work to single-row plots as used in experiment A. The treatments are:

(a) Simazine (2.5 lb)

(b) Monuron (3.5 lb)

(c) Propham (4.0 lb) + 2,4-DES (4.6 lb)

(d) 2,4-DES (4.6 lb) + fenuron (0.5 lb)

These were applied to the entire plot surfaces (i.e. from the inward-facing side of one guard row to that of the next) on 10 April 1959, nine days after planting, and were re-applied on 1 April 1960.

In both experiments the herbicides were applied by Oxford Precision Sprayer in volumes of liquid equivalent to 30 gal/ac.

RESULTS

Experiment A

Yield. Table I shows the fruit yields of experiment A from 1958 to 1960. The TCA/dinoseb plots have given the poorest crop each year, and their present total yield is significantly below that of any other treatment. The differences in total yield between the other treatments are not significant.

TABLE I. EXPERIMENT A: FRUIT YIELDS IN CWT/AC.

Treatment	1958	1959	1960	Total
(a) TCA + dinoseb	33.7	44.2	85.5	163.4
(b) Propham + 2,4-DES	50.0	61.6	105.4	217.0
(c) Propham + fenuron	41.8	66.8	102.3	210.9
(d) 2,4-DES + fenuron	43.0	60.1	96.3	199.4
(e) Control	49.8	53.8	98.5	202.1
Sig. diff. (P = 0.05) between treatment (e) and any other treatment				20.5
" " " " treatments (a), (b), (c) and (d)				23.7

Cane growth. After routine stooling-up in autumn, when the remaining sucker canes are removed together with any broken, weak, severely diseased or badly misplaced new stool canes, the procedure is to count and measure the sound new stool canes available in each plot. These are then thinned to an average of not more than 7 per stool subject to a maximum of 8 on any stool. The canes left are next laced to the wires and tipped, usually at a height of 5 ft, and the proportion of canes reaching this height is recorded.

Table II shows the numbers of canes present before and after thinning during the winters from 1957/58 onwards. In 1957/58, before the application of herbicides, the differences in average cane number between the five sets of plots were not significant. By 1958/59 the TCA/dinoseb plots had the fewest canes, although

TABLE II. EXPERIMENT A: NUMBERS OF NEW CANES PRESENT PER PLOT

	1957/58		1958/59		1959/60	
	Before thinning	After thinning	Before thinning	After thinning	Before thinning	After thinning
(a) TCA + dinoseb	39.2	38.7	41.0	37.2	58.8	49.7
(b) Propham + 2,4-DES	42.5	41.3	46.8	43.0	74.2	63.2
(c) Propham + fenuron	37.8	37.0	50.3	46.7	70.0	60.3
(d) 2,4-DES + fenuron	36.5	35.3	49.7	44.8	64.5	57.5
(e) Control	41.9	40.0	44.6	40.3	67.3	75.9
Sig. diff. (P = 0.05) between treatment (e) and any other treatment			8.9	7.6	11.6	8.1
Sig. diff. (P = 0.05) between treatments (a), (b), (c) and (d)			10.2	8.7	13.4	9.3

they differed significantly in average number only from the propham/fenuron plots, and then only after thinning. In 1959/60, however, the TCA/dinoseb plots before thinning had significantly fewer canes than those of one other treatment (2,4-DES/propham), and after thinning they had significantly fewer than those of three other treatments. The measurements of the canes, not yet analysed, suggest that the TCA/dinoseb treatment also caused a slight reduction in average cane length. When applied each spring this mixture caused scorching, distortion and death of many emerging young canes and of some of the lowermost laterals of the fruiting canes.

Weed Counts. Counts of total weed seedlings were taken in 1958 on 5 June and 4 July, by throwing eight and ten 6-in. quadrats/plot respectively, and on 9 June 1959 by throwing five quadrats. The results, summarised in Table III, show that all four chemical treatments largely reduced the weed population, especially in 1959, but not to the extent of eliminating the spring weed problem completely. The second count in 1958 was made because it seemed at the time of the June count that many seedlings present on the propham/2,4-DES and propham/fenuron plots would die, and this in fact happened. The figures shown have not been analysed statistically. The weeds on the herbicide-treated plots included most of the species present on the controls, and it is not possible from these data alone to point to any clear selective effects of the individual treatments. In 1960, when no weed count was taken, the degree of control resembled that of 1959.

TABLE III. EXPERIMENT A: NUMBERS OF WEED SEEDLINGS PER SQUARE FOOT OF SOIL SURFACE

Treatment	5/6/58	4/7/58	9/6/59
TCA + dinoseb	54.3	63.7	4.1
Propham + 2,4-DES	67.0	38.5	8.3
Propham + fenuron	150.6	80.3	6.3
2,4-DES + fenuron	80.0	80.6	8.9
Control	239.6	*No count	66.9

* Plots hoed in mid-June.

Experiment B

Yield. Fruit yields for the first two years of experiment B are included in Table IV. The main feature is the poor performance of the control plots, caused by their having been allowed to become heavily weed-infested in spring 1959 as a contrast to the herbicide-treated plots, which remained clean. The plots of the five treatments are now being managed independently, each set being hoed for sucker and weed control when necessary and a record kept of all cultivations; but the control plots may take some time to recover from their check. The simazine plots, highest in yield so far, have shown good growth and no chemical injury, while the monuron plots, the lowest in yield of the chemical treatments, have shown some leaf chlorosis: but none of the cropping differences associated with the chemical treatments have yet reached significance level.

TABLE IV. EXPERIMENT B: FRUIT YIELDS AND CANE GROWTH

Treatment	Fruit yield (cwt/ac)			New Canes in 1959/60	
	1959	1960	Total	Av no./plot	Av length (in)
(a) Simazine	3.0	47.0	50.0	48.5	42.2
(b) Monuron	2.5	39.6	42.1	45.0	41.3
(c) Propham + 2,4-DES	2.8	45.8	48.6	45.3	42.6
(d) Fenuron + 2,4-DES	2.8	43.4	46.2	43.5	40.6
(e) Control	1.4	20.7	22.1	24.7	32.2
Sig. diffs. (P = 0.05)			9.4	7.4	

Cane growth. Table IV also gives the numbers and average lengths of the new canes present in the winter of 1959/60. Since thinning was unnecessary, these were the numbers of canes tied-in for fruiting in 1960, and as the plantation was only a year old they were left at full length and arched-over on a single wire. There is obviously a close parallel between these figures and the data for yield.

Weed Counts. Table V gives counts of total weeds taken on arbitrarily selected dates in 1959 and 1960. All four herbicide treatments markedly reduced the weed population, but the effects of simazine and monuron were outstanding. In 1959 the four treatments gave adequate weed control up to 20 June, when all the rows of the experiment were hoed and the alleyways lightly rotavated because of the weed growth on the control plots and the general need for destruction of sucker canes. Much less time was required to hoe the treated rows, however, than the controls. A striking effect afterwards was that the simazine and monuron plots continued to remain clean, even after a second rotary cultivation on 20 August. In late November their weed cover was still estimated at below 5 per cent, and consisted mainly of young seedlings. The propham/2,4-DES and fenuron/2,4-DES mixtures showed no evidence of residual action after cultivation.

TABLE V. EXPERIMENT B: NUMBERS OF WEED SEEDLINGS PER SQUARE FOOT OF SOIL SURFACE ON DATES IN 1959 AND 1960

Treatment	16 June 1959		11 May 1960	
	No. of seedlings	Main species	No. of seedlings	Main species
Simazine	1.9	*Viola* spp.(38) *Polygonum* spp.(19)	1.5	*Viola* spp.(35) *Polygonum* spp.(30)
Monuron	2.9	*Viola* spp.(38) *Fumaria officinalis* (18) *Polygonum* spp.(10)	1.1	*Viola* spp.(40) *Fumaria officinalis* (20) *Veronica* spp.(20)
Propham + 2,4-DES	4.9	*Chenopodium album* (36) *Fumaria officinalis* (11)	13.2	*Chenopodium album* (44) *Stellaria media* (16) *Viola* spp.(11)
Fenuron + 2,4-DES	6.1	*Chenopodium album* (34) *Stellaria media* (23)	9.5	*Stellaria media* (44) *Chenopodium album* (16)
Control	49.8	*Chenopodium album* (38) *Stellaria media* (16) *Poa annua* (12)	51.7	*Stellaria media* (36) *Chenopodium album* (28)

(The figures in brackets show the approximate percentage incidence of the main species.)

DISCUSSION

These results strongly suggest that some of the chemical weedkillers now available will prove useful in raspberry growing. Chemical weed control could not only ease the task of cleaning large acreages for annual weeds two or three times in spring and early summer, but could prevent the unchecked growth of weeds that usually occurs in late summer and autumn, when mechanical cleaning is impracticable.

Some confirmation of the results with simazine is already coming forward from growers, and if this herbicide proves successful in long-term use it should become a valuable asset. The results with monuron seem at present less satisfactory in that some crop injury has occurred, but with a perennial plant like the raspberry the possible doses and times of application of any weedkiller leave considerable room for manoeuvre. Of the mixtures tried, none has so far given such good weed control as simazine or monuron. That of TCA and dinoseb has caused severe damage, attributed to the TCA component. Propham/2,4-DES mixtures appear to be safe, and if used under suitable conditions will usually control Stellaria media, Senecio vulgaris, Poa annua, Capsella bursa-pastoris and some other annuals: but this combination of herbicides is unlikely to be as successful in raspberry fruiting plantations as in cane nurseries (Wood and Sutherland, 1960), where it is aided by the dense shade of the cane crop. Even if some such weedkiller as simazine should prove outstandingly successful, however, there may still be reason to vary the herbicide programme from time to time, in which case some of the mixtures now on trial may be useful.

The use of long-term trials yielding reliable quantitative data appears to be the only sound way of assessing the usefulness and safety of herbicides for such a crop as raspberries. Plantation performance varies from year to year under the influence of a large number of factors often difficult to evaluate, and short-term herbicide trials of an "observational" nature may therefore easily produce false conclusions. The present experiments will be more fully reported later.

Acknowledgments

Thanks are expressed to Fisons' Pest Control, Ltd. and the Mirvale Chemical Co. Ltd. for supplying materials used in this work.

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EFFECTS OF SOME CHEMICAL WEEDKILLERS ON A RASPBERRY CANE NURSERY: A PROGRESS REPORT

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Summary. After preliminary trials of herbicides in raspberry cane nurseries between 1955 and 1958, monuron, simazine and a 2,4-DES/propham mixture were chosen for inclusion in a longer-term trial planted in 1958. No hand cultivation has so far been required in this trial following spring applications of simazine at 2 lb or 3 lb/ac, and very little following the use of monuron at 3 lb. Lower doses of monuron and simazine, and the mixture of 2,4-DES (3.6 lb) with propham (5.0 lb) have not eliminated the need for cultivations. Higher yields of cane, of better quality, have been harvested from the plots on which herbicides have effectively replaced cultivations. A preliminary test on the persistence and movement of simazine and monuron in the soil is also reported.

INTRODUCTION

At the Fourth British Weed Control Conference, in 1958, the weed problem in raspberry cane nurseries (spawn beds) was described and a report was given on preliminary trials with chemical herbicides (Wood & Sutherland, 1960). It was shown that of various herbicides tested between 1955 and 1957, none used singly controlled a sufficiently wide range of weed species, and at least two, chlorpropham and TCA, caused injury to raspberry canes. Mixtures of herbicides were tried in 1957, but at safe doses none of the combinations used had a sufficiently long residual action to give the degree of weed control desired. Mixtures of 2,4-DES and propham were the most successful. A small trial early in spring 1958 tested diuron and monuron, each at 0.5 lb and 1 lb, and simazine at 1 lb and 2 lb. These showed promise, and monuron and simazine were chosen for a new trial, started later in the same spring, which is the subject of this report. A 2,4-DES/propham mixture was also included. This trial gave its first cane crop in autumn 1959 and will be re-cropped at least once more.

METHODS AND MATERIALS

Field procedure

The experimental nursery was planted in May 1958, with canes of the variety Malling Exploit, in four rows 6 ft apart and with the canes spaced at 3 ft in the rows. Unit plots 8 yd x 2 yd were marked out at right angles to the direction of the rows. The treatments, each applied to three plots chosen at random,

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were simazine at 1 lb, 2 lb and 3 lb; monuron at 1 lb, 2 lb and 3 lb; 2,4-DES (3.6 lb) + propham (5.0 lb) and control (hand cultivation). The herbicide treatments were applied each spring by Oxford Precision Sprayer. The treated plots afterwards received hand cultivation where this was necessary because of weed growth.

In 1958 the herbicides were applied on 16 June, each at a liquid volume rate of 40 gal/ac. The planted canes were then in leaf and the young canes a few inches high. The whole experiment was cultivated in late August, by which time the control plots had become badly weed-infested. In early March 1959, after the one-year-old stools had been dug out in accordance with normal practice (Wood, 1949), the whole area was sprayed with diquat (2 lb in 25 gal/ac) to destroy over-wintered weeds. Nevertheless, all the plots except those receiving simazine at 2 lb and 3 lb and monuron at 3 lb still required hoeing before the main treatments could be re-applied, and this probably destroyed some emerging young canes. The main treatments were re-applied on 19 March, again in 40 gal/ac. Weed growth afterwards developed fairly heavily on the 2,4-DES/propham, monuron 1 lb and control plots, but, owing to the risk of damage to young canes, hoeing was postponed until 19 June. All the plots were then hoed except those treated with simazine at 2 lb and 3 lb, which were clean. Weed control later in 1959 was aided by the shade of the cane crop. After the canes had been harvested the ground was cultivated early in 1960 for weed control and levelling, and the treatments were re-applied on 4 March at a volume rate of 30 gal/ac, without a prior diquat spray.

Testing for herbicide persistence

Introductory work to test for the persistence of simazine and monuron at various soil levels was started in August 1959, five months after the application of the sprays that year. Samples were taken from the control plots, the 2 lb and 3 lb monuron plots and all the simazine plots, and were drawn from three soil levels, namely 0 - 1 in., 1 - 3 in. and 3 - 6 in. The sample for any one depth on a given plot was made up from three random borings. Each sample was used to fill three 3½ in. pots, into which were sown, as test plants, swedes, Blenda oats and Arctic King lettuce.

RESULTS

Yield and quality of canes

The productivity of a cane nursery of any given variety of raspberry largely reflects the efficiency and care exercised in weed control. Not only do weeds compete with the crop, but cultivations for their control destroy emerging young canes. An ideal method of weed control would therefore be provided by a herbicide which, when sprayed on to the clean nursery in spring, kept the ground weed free for most of the growing season without injury to the crop.

Table I shows the numbers and grading of canes harvested from this trial in winter 1959/60. The marginal overlap between the plots is a large source of error, and a statistical analysis of these results has not yet been made. The figures, however, support the visual observation that cane growth was distinctly best on the 2 lb and 3 lb simazine plots and good also on the 1 lb simazine and 3 3 lb monuron plots. Not only were there more canes from the better treatments, but the canes were larger. Also as reflected in the figures, growth on the monuron plots was never quite as good as on those treated with simazine, but this may have been a result of severe chlorosis caused to the mother stools sprayed with monuron when in full leaf in June 1958. Spraying with any suitable residual herbicide would normally be done earlier. The simazine and 2,4-DES/propham sprays also caused slight leaf chlorosis in 1958, but none of the treatments did so when applied at correct times in 1959 and 1960. Visual differences between car growth on the monuron and simazine plots have been less obvious in 1960.

TABLE I. AVERAGE YIELDS OF CANE PER PLOT, WINTER 1959/60

Treatment	No. of canes	per cent 1st grade	per cent 2nd grade
Simazine 1 lb	147	73	27
" 2 "	181	78	22
" 3 "	170	74	26
Monuron 1 "	87	62	38
" 2 "	79	70	30
" 3 "	104	76	24
2,4-DES (3.6 lb)/propham (5 lb)	109	58	42
Control	93	50	50

Samples of canes dug from all the treatments in 1959 were heeled-in for observation in 1960. All came normally into growth.

Weed counts

Weed counts made on single dates in 1958, 1959 and 1960 are given in Table II. All the chemical treatments, but least those of simazine at 1 lb and monuron at 1 lb and 2 lb, gave good weed control following the initial applications in 1958. Thereafter the simazine treatments, particularly the two higher rates, became clearly the best and the 1 lb monuron and 2,4-DES/propham treatments the poorest.

TABLE II. COUNTS OF TOTAL WEEDS PER SQUARE FOOT ON DATES IN 1958, 1959 & 1960

(Based on ten 6 in. quadrats per plot in 1958 and eight in 1959 and 1960.)

Treatment	Weeds/sq ft on 17.7.1958	1.6.1959		26.5.1960	
		No. of species	Weeds/sq ft	No. of species	Weeds/sq ft
Simazine 1 lb	12	7	4	9	12
" 2 lb	6	3	0.5	1	1
" 3 lb	3	1	0.2	2	0.7
Monuron 1 lb	24	8	68	9	644
" 2 lb	14	9	46	9	49
" 3 lb	8	5	14	7	29
2,4-DES 3.6 lb + Propham 5 lb	9	12	47	14	586
Control	72	13	160	15	644

N.B. In the 1959 and 1960 records a miscellaneous group of less common weeds has been counted as a single species.

The 1958 count was on total weeds only, but in the later counts the most frequent species or groups of closely allied species were recorded separately. The number of these in 1959 was 12, plus a "miscellaneous" group of less common weeds, and in 1960 it was 13 plus a miscellaneous group. For simplicity, the miscellaneous group for each year has been included in Table II as a single species.

The simazine and highest-dose monuron treatments clearly reduced both the numbers of species present and the numbers of individual weeds. In 1959 their effects persisted until the next time of spraying, in spring 1960, whilst none of the other treatments gave more than a temporary control of weed growth. Similar differences have been apparent in 1960, except that the plots with poor weed control have become increasingly dirty because of the inherent difficulty in cleaning cane nurseries by ordinary methods of cultivation.

Table III lists the weed species which have so far proved regularly persistent under the three most effective treatments.

TABLE III. WEED SPECIES PERSISTENT ON SIMAZINE AND MONURON-TREATED PLOTS

Treatment	1959	1960
Simazine 2 lb and 3 lb	Vicia hirsuta Polygonum aviculare " convolvulus	Vicia hirsuta
Monuron 3 lb	Veronica persica Fumaria officinalis Polygonum aviculare " convolvulus	Veronica persica Fumaria officinalis Senecio vulgaris

Herbicide persistence

Table IV shows the results of the 1959 test for herbicide persistence and movement in the soil. At five months after spraying there was no evidence of the presence of seriously toxic quantities of monuron or simazine below the top inch of soil. The results from the 2 lb simazine plots, which gave slight evidence of a downward movement of herbicide, could have been due to accidental mixing of samples. The rainfall during the five months was 8.31 in, compared with the average for the same period of 10.4 in. Weeds germinated freely in the soil from the control plots and from below the 1 in. level on other plots.

TABLE IV. RESULTS OF HERBICIDE PERSISTENCE TEST, 1959

		Control	Sim 1 lb	Sim 1 lb	Sim 3 lb	Mon 2 lb	Mon 3 lb
Top ten	Swedes	+	xx	xxx	xxx	xxx	xxx
	Lettuce	+	xx	xxx	xxx	xxx	xxx
	Oats	+	xx	xxx	xxx	xxx	xxx
1 in.-3 in.	Swedes	+	+	x	+	+	+
	Lettuce	+	+	x	+	+	+
	Oats	+	+	x	+	+	+
3 in.-6 in.	Swedes	+	+	+	+	+	+
	Lettuce	+	+	+	+	+	+
	Oats	+	+	+	+	+	+

Key to behaviour of test plants:

+	Normal
x	Some stunting
xx	Severe stunting
xxx	Death

DISCUSSION

These results show that simazine and monuron have so far been the most successful herbicides tested as weedkillers in raspberry cane nurseries. As in other work with raspberries, monuron has caused some temporary crop injury, but this danger may well be overcome by modifications in doses and times of use. A mixture of 2,4-DES and propham was less successful, but this and other mixtures may be useful as alternative treatments, especially on soils where the weed population has already been well reduced.

The test made in 1959 on herbicide persistence and movement in the soil showed that simazine and monuron, applied at low doses, can persist for at least five months in the top inch layer of soil in quantities lethal to seedlings of swede, oat and lettuce. There was no certain evidence of movement to a lower depth within that period.

Acknowledgments

Thanks are expressed to Fisons' Pest Control Ltd. and to the Du Pont Co. (U.K.) Ltd. for supplying materials used in this work.

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EXPERIMENTS WITH DALAPON IN SOFT FRUIT CROPS

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Summary. In 1959 and 1960, serious damage occurred on fruiting canes of Lloyd George raspberries where dalapon had been applied at 3.7 lb/ac during the previous autumn. Doses of 3.7 and 7.4 lb/ac caused no injury on several varieties when applied during the winter, however, and three successive annual treatments in December had no adverse effect on two varieties. In blackcurrants, repeated annual treatments since 1957 at 7.4 lb/ac during the growing season caused no injury to the variety Davison's Eight. Other varieties also tolerated this treatment but, in one experiment, a single application of 14.8 lb/ac in September slightly reduced growth in the following year. No injury was evident on well-established gooseberries following application at 7.4 lb/ac between September and March. It is concluded that in these crops, dalapon at 3.7 lb/ac during the winter is useful for the control of Poa annua and some other grasses. In raspberries this treatment only appears safe between mid-November and mid-January but with black-currants and gooseberries much more latitude in timing and dose seems possible.

INTRODUCTION

Published reports on the use of dalapon in raspberries record variable results. Injury has been caused in some trials, (Neilson, 1955; Davison et al, 1955; Wilson, 1957; Dodge & Snyder, 1958; Anon, 1959; Robinson 1960 b; Wood and Sutherland, 1960), but not in others (Carlson, 1955, 1955 a, b; White, 1958; Anon, 1958 c; Cartwright, 1958; Montgomery, 1959; Robinson, 1960 b).

Results on blackcurrants have been more consistent. In W. Ontario, no injury was caused by 6 lb of commercial product per acre (Neilson, 1955) and, in a trial in the U.S.A., resistance was fair to good (Anon, 1958 d). No injury was recorded on blackcurrants in Northern Ireland (Anon, 1957 a; Robinson 1958, 1960), and in trials carried out by the N.A.A.S, 6 and 8 lb/ac applied after harvest had no adverse effect (Anon, 1958 a). In Tasmania, rates of 10 to 20 lb/ac in the spring or autumn are recommended for control of all grasses in this crop (Anon, 1957 b).

Little information is available in the literature on the use of dalapon on gooseberries. In Canada no injury was caused by 6 lb/ac of commercial product (Neilson, 1955) nor in Northern Ireland by January and May application of 3.75 lb/ac, although slight injury appeared where double this rate was used in February and more severe damage was caused by 15 and 30 lb/ac (Robinson, 1960 a). The damage was temporary, however, even at the highest rate. In Lincolnshire, 5 lb/ac caused no damage in December, but bushes up to three years old were damaged by a late April application. (Anon, 1958 b).

On account of the prevalence of Poa annua in Northern Ireland and its susceptibility to dalapon, further trials were conducted in 1959 and 1960 in raspberry, blackcurrant and gooseberry plantations.

METHODS AND MATERIALS

In most of the experiments, the methods used were similar to those described in the previous paper, but in gooseberries and blackcurrants, treatments were applied as a directed spray to the entire area, except where stated otherwise.

The terminology, adopted by Wood and Robertson (1957) to describe the types of laterals and inflorescences produced on raspberries, has been used in this paper. The data on lateral formation in raspberries, presented in table I, are based on all cropping nodes on 30 canes selected at random from each plot.

RESULTS

Raspberries

Trials were conducted between 1958 and 1960 to obtain information on the response of raspberries to dalapon* applied at different times of the year.

In the first trial, single plots of the variety Lloyd George, planted in February 1957, were sprayed at 3.7 lb/ac during the first week of each month from October 1958 until April 1959. No obvious phytotoxic effects occurred following application between December and February, but treatments applied earlier or later than this period caused some injury. The type of damage resulting from application in the autumn differed from that caused by treatment in the spring. On plots treated in October or early November fruiting laterals appearing in April were reduced in size and bore small berries which crumbled easily. Damage was more severe towards the tops of the canes and in many cases where the fruiting lateral from the main or primary bud at a node was stunted or killed, a short lateral had been produced from the secondary bud immediately below the main one.

March and April applications caused no obvious injury to the fruiting canes but checked the emergence and growth of young spawn. This injury was only temporary, however, and later growth was normal.

A similar unreplicated trial on Lloyd George was conducted the following year. Dalapon at 3.7 lb/ac was applied at weekly or fortnightly intervals between 31st August and 9th November 1959 and between 5th February and 6th April, 1960. The symptoms of injury in spring 1960 were similar to those recorded the previous year. Table I shows that applications between 31st August and 19th October stunted the fruiting laterlls, and increased the number of nodes bearing both primary and secondary laterals. Although the number of inflorescences was increased by treatment during this period, the crop yield was markedly decreased because of reduction in the vigour of the fruiting laterals and also in the number of flowers produced per primary lateral. The fruit was also small and of poor quality. There was no obvious difference between treatments in the number of flowers on secondary laterals.

Plots sprayed on 3rd November 1959 or later, showed no obvious injury symptoms on fruiting canes. Where treatment had been applied on 28th March and 6th April, similar damage to that recorded in the previous year occurred on the young canes.

* Commercial product - Dowpon containing 74 per cent a e of dalapon and a wetting agent.

A similar treatment applied between mid-September and mid-November 1959 caused no obvious injury to the raspberry varieties Malling Jewel, Malling Landmark, Malling Exploit and Seedling V. Length of fruiting lateral and number of berries per lateral were not affected and there was no apparent difference in crop yield or quality between sprayed and unsprayed plots.

The effect of applying dalapon at different times was also tested in a cropping experiment on the variety Lloyd George in 1959/60. A dose of 3.7 lb/ac was applied in December, February and April and compared with a hand-hoed control plot. Treatment in December and February caused no apparent injury, but application in April slightly retarded the emergence and growth of young canes. This check was only temporary, however, and at the end of the season, the number and height of canes on sprayed plots did not differ significantly from the control. None of the treatments caused any obvious injury on fruiting canes, but plots sprayed in April gave a significantly lower yield ($P = 0.05$) than the control (table II).

TABLE I. EFFECT OF TIME OF APPLICATION OF DALAPON ON LLOYD GEORGE RASPBERRIES

Date of application of dalapon 3.7 lb/ac	Fruiting canes - 1960					
	Percentage* of nodes furnished with:			Mean length of primary and secondary laterals ✝ cm	No. berries/ primary lateral✝	Yield/ plot of 4 yd row
	primary laterals	secondary laterals	primary + secondary laterals			
31/8/59	44.4	7.5	38.9	5.6	5.4	9.8
7/9/59	53.5	7.3	32.3	7.2	6.1	10.8
21/9/59	64.4	11.9	20.3	5.8	5.3	7.1
5/10/59	47.5	10.9	25.0	7.3	5.3	6.7
19/10/59	58.1	10.5	27.5	9.8	5.8	7.3
3/11/59	83.1	3.4	11.9	14.1	9.7	14.3
9/11/59	85.2	3.7	8.7	13.0	9.8	17.9
5/2/60	82.1	6.0	10.4	13.2	9.3	13.2
20/2/60	88.7	2.1	7.2	12.0	8.5	10.4
4/3/60	86.4	4.9	8.6	14.9	9.6	11.6
11/3/60	88.0	5.4	8.7	13.7	8.8	10.7
28/3/60	73.0	8.1	8.9	14.0	8.5	12.1
6/4/60	78.3	4.9	9.1	13.3	8.0	10.3
Untreated	87.8	5.5	8.0	13.0	9.1	15.7

* Nodes with tertiary laterals are omitted from this table.

✝ Data taken on 4th or 5th node from top of cane.

TABLE II. COMPARISON OF APPLICATION OF DALAPON AT 3.7 LB/AC ON RASPBERRIES AT DIFFERENT TIMES (THREE REPLICATES)

Date of application	Yield in lb/ plot of 8 yd row July 1960
1/12/59	40.5
4/2/60	45.6
7/4/60	35.2*
Untreated	43.8

S.E. of difference ±2.98

* Differs significantly from untreated plot at 5% level (P = 0.05)

In a trial started in December 1957, dalapon at 3.75 lb/ac was compared with a hand-hoed control on Malling Landmark and Malling Jewel. The sprayed plots were treated again at 7.4 lb/ac in December 1958 and also in December 1959. Treatments were replicated twice on each variety and all plots were hand-hoed whenever necessary during the course of the experiment. There was no indication that the repeated use of dalapon in mid-winter had any adverse effect on crop yield, as may be seen in table III. Cane measurements at the end of the third season showed no loss of vigour compared with hand-hoed control plots.

TABLE III. EFFECT OF REPEATED SPRAYS OF DALAPON ON RASPBERRIES

Variety	Year	Yield in lb/ plot of 6 row yd	
		Hand-hoed) 30/12/57, 30/12/58, 30/12/59	Dalapon) 3.75 lb/ac - 30/12/57, 7.4 lb/ac - 30/12/58, 7.4 lb/ac - 30/12/59
Malling Jewel	1958	27.7	28.5
	1959	27.4	28.1
	1960	20.3	23.2
Malling Landmark	1958	28.7	25.1
	1959	18.8	21.2
	1960	20.6	22.4

In tests on the effect of overall applications of certain herbicides on Lloyd George raspberries in January 1959 and February 1960, dalapon at 7.4 lb/ac caused severe damage. In the spring leaves on fruiting canes were stunted and chlorotic and some were killed. Fruiting laterals were less severely injured than the foliage but some terminal flower buds failed to open.

Blackcurrants

To test the tolerance of blackcurrants to dalapon, a dose of 14.8 lb/ac was applied to an area of 100 sq ft around single bushes of Boskoop Giant each month from October 1958 till April 1959. A similar area was treated around Cotswold Cross bushes each month from August 1959 till March 1960. On each spraying date a similar bush was sprayed overall at a rate equivalent to 3.7 lb/ac in 100 gal of water/ac. Ground applications caused no apparent injury to the vigour of the bushes and crop records showed no marked reduction in yield. Overall sprays had no obvious adverse effect except when applied after bud burst.

High doses of dalapon applied in the autumn and spring were compared with a hand-hoed control in 1959/60. Treatments were as shown in table IV and each was replicated four times on plots containing 4 nine-year-old bushes of each of the varieties Goliath, Wellington XXX and Seabrooks Black. No phytotoxic effects were observed on the foliage in autumn 1959 or during 1960 nor were crop yield or the amount of young growth significantly affected (table IV). In this experiement, however, the amount of new wood produced on each of the three varieties, following a single application of 14.8 lb/ac in September, was slightly less than on the hand-hoed control.

TABLE IV. EFFECT OF HIGH DOSES OF DALAPON ON BLACKCURRANTS (FOUR REPLICATES)

Dalapon, lb/ac per treatment	Times of application	Yield lb per plot of 12 bushes July 1960	One-year-old wood, ft per bush September 1960
0	-	68.9	119.6
7.4	29/9/59 and 24/3/60	76.1	122.6
14.8	29/9/59	60.3	104.5
14.8	24/3/60	67.0	114.1
7.4	29/9/59, 24/3/60 and 5/5/60	63.7	119.3
S.E. of difference		±8.5	±8.2

In a long-term experiment on the effect of the elimination of hand-hoeing around blackcurrants, dalapon has been used, along with simazine and other herbicides, to maintain plots of Davison's Eight in a weed-free condition since spring 1957. Four applications of dalapon at 7.4 lb/ac and one application at 3.7 lb/ac have been made in four years during the growing period without causing any check to growth. In 1960 crop yield on sprayed plots was higher than on hand-hoed plots, but the increase just failed to be significant ($p = 0.05$).

Gooseberries

The effect of autumn, winter and spring applications of dalapon was compared on gooseberries in 1959/1960. The bushes were eight years old and were planted

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to be very promising for runner inhibition in strawberries grown on this system Thompson (1960) has shown that it is also effective when used to give complete runner control of strawberries growing in rows as single plants and (1961) has suggested that, in fact, it may be more reliable when used for this purpose than in systems in which rooted runners are already present such as the 'matted row' and 'matted bed'.

In this paper a short description is given of the pattern of runner production during the summer, as this governs the choice of times of application of maleic hydrazide, and an experiment is described in which successful runner control was achieved in four varieties growing in the field, using two separate sprays of maleic hydrazide during the summer.

METHODS, MATERIALS AND RESULTS

Pattern of runner production in field

Young plants of the varieties Talisman, Redgauntlet, Cambridge Favourite and Cambridge Vigour were planted in the field in April. During the summer runners were removed from 120 plants of each variety on the following dates; 26th June, 14th July, 10th August and 27th August. Table I shows, for each variety, the rate of primary runner production, that is runners growing directly from the parent plant, expressed as the mean daily production of runners for every 100 plants between each removal date.

TABLE I. MEAN RUNNER PRODUCTION PER 100 PLANTS BETWEEN SUCCESSIVE DATES DURING THE SUMMER

Variety	Mean daily production between given dates			
	16-26 June	26 June-14 July	14 July-10 August	10-27 August
Redgauntlet	17	18.3	29	38
Talisman	28	25.0	53	71
Vigour	3	13	19	22
Favourite	13	11	20	35

It is clear that the peak rate was reached in the second half of August, just before primary runner production ceased early in September. This is to be expected as the plants produce new branch crowns during the summer and hence increase the effective rate of leaf production and the number of sites available for runner initiation.

Primary runners formed in late August, however, contribute relatively little to the mats of runners found in neglected strawberry plantations, and it is the early-formed runners, particularly those produced in early July, which it is most important to control. This is illustrated in Table II which shows the mean number of secondary runners produced from the first seven primary runners emerging from six plants of Talisman growing in the field, and counted on 15th August. Out of a mean total of 56 runners/plant, 30 are derived from the first two primary runners.

It is quite clear that one cannot equate the large numbers of relatively unimportant primary runners produced in late August with the few produced during July, and that for effective control it is the latter which it is most important

THE USE OF MALEIC HYDRAZIDE FOR THE CONTROL OF RUNNERS IN STRAWBERRY PLANTATIONS

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Summary: Maleic hydrazide as the triethanolamine salt was used to control runner production in four varieties of strawberry; Talisman, Redgauntlet, Cambridge Vigour and Cambridge Favourite. Records of primary runner production in the field showed that runners emerging during July gave rise to large numbers of secondary runners, and it was necessary to inhibit these, rather than the runners formed in the second half of August for successful control. Maleic hydrazide was applied on 23rd June at 0.1, 0.15 or 0.2 per cent. The plants were resprayed when healthy young runners were again seen emerging. Successful runner control was achieved with all treatments in the varieties Talisman, Cambridge Vigour and Cambridge Favourite. In Redgauntlet a few plots of all treatments were only marginally controlled. Comparison of the height of treated with untreated plants in the following spring showed a slight reduction in the treated series. The crop from treated plants of Talisman and Redgauntlet was approximately equivalent to that taken from control plants from which all runners had been removed at intervals by hand. In Cambridge Vigour and especially Cambridge Favourite the crop was reduced. It is believed that the latter result may have been due to poor establishment of the plants at the time of treatment.

INTRODUCTION

All commercial strawberry varieties grown in Britain produce stolons in long days during the summer. Although cultural systems such as those known as the 'matted bed' and the 'matted row' have been devised to take advantage of these runners the simplest and most easily managed system is to remove all runners and grow the plants in rows as individual units. With the leafy, vigorous varieties now being widely grown this latter system is almost essential for the successful control of grey mould (Botrytis cinerea).

In the North it is difficult to obtain sufficient early-formed runners in time for autumn planting, and it is more usual to establish plantations in the spring, to deblossom in their maiden year, and to take the first crop in the following year, fifteen months after planting. Runners formed during this period act as weeds in the sense that they compete with the parent plants for water and nutrients, and their presence, if allowed to grow unchecked, not only greatly reduces the cropping capacity of the plantation but impedes routine cultural operations.

A variety of chemicals have been tried for runner control in the past (Carlson 1953, Denisen 1955) but of these only maleic hydrazide has proved to give a reasonable level of runner inhibition without severely damaging the parent plant. Denisen (1950) first reported maleic hydrazide as a possible means of controlling runner production in strawberries grown in matted beds. Since then further publications by Denisen (1956) and Hitz (1959) have shown this substance to control. This means that the first spray application must be applied sufficiently early to inhibit the development of early runners. Moreover there is no need to risk interfering with flower initiation by applying maleic hydrazide later than mid-August, since a spray at this time will inhibit all but a few unimportant runners produced at the end of the season.

TABLE II. NUMBERS OF SECONDARY RUNNERS PRODUCED BY SUCCESSIVE PRIMARY RUNNERS OF THE VARIETY TALISMAN (RECORDED 15TH AUGUST 1960)

Mean no. of secondary runners			
Primary runners	Rooted	Unrooted	Total
1st	3	13	17
2nd	3	9	13
3rd	1	6	8
4th	1	4	6
5th	0.8	4	5.8
6th	0.3	2	3.3
7th	0.1	2	3.1
		Total	56.2

Application of maleic hydrazide in the field

The following four varieties were planted in April 1959 in the field; Talisman, Redgauntlet, Cambridge Favourite and Cambridge Vigour. They were allowed to grow on until the first runners started to appear towards the end of June when the first treatments were applied. All plants, except for the control, were sprayed on 23rd June with maleic hydrazide as the diethanolamine salt at a rate equivalent to 0.1, 0.15 or 0.2 per cent of active ingredient. The plants were then resprayed when actively growing young runners were again found emerging. In the case of plants treated at 0.1 and 0.15 per cent the sprays were repeated on 22nd July at the same levels as on the first occasion. It was not found necessary to respray plants sprayed on the first occasion at 0.2 per cent until 13th August when they were resprayed at 0.1 per cent. At this time it was also considered necessary to spray Redgauntlet plants, previously twice treated at 0.1 per cent for a third time.

A further control set of plants was left unsprayed. Runners growing from these plants were removed and counted at intervals through the season so that the plants remained free of established runners. The experiment was divided into four blocks with all treatments represented at random in each block in plots of thirty plants to give a total of 120 plants per treatment.

The sprays were applied with an Oxford Precision Sprayer at a rate equivalent to 60 gal/ac. Only the parent plants were sprayed, and on occasions when runners were present between the rows these were not deliberately sprayed.

During the summer records were made of the appearance of the plants and the degree of runner inhibition. In the following year measurements were made of

TABLE V. NUMBER OF FLOWER TRUSSES PER PLANT AND WEIGHT OF FRUIT (OZ PER PLANT) FROM FOUR VARIETIES OF STRAWBERRIES AFTER TREATMENT WITH MALEIC HYDRAZIDE IN THE PREVIOUS YEAR

Variety	Concentration (per cent) and dates of spray			Control
	0.1 23.6 0.1 22.7 0.1 13.8*	0.15 23.6 0.15 22.7	0.2 23.6 0.1 13.8	
Redgauntlet				
No. of trusses	5.1	4.8	4.6	4.4
Crop picked ÷	16.9	15.6	15.6	13.7
Talisman				
No. of trusses	8.5	11.9	9.6	12.2
Crop picked ÷	23.2	26.1	24.4	26.9
Cam. Vigour				
No. of trusses	7.3	9.3	7.5	9.9
Crop picked ÷	19.4	25.4	22.4	25.7
Cam. Favourite				
No. of trusses	4.3	5.2	6.0	8.3
Crop picked ÷	11.9	13.0	16.1	21.1

÷ Sig diff 2.3 oz/plant

* Applied only to the variety Redgauntlet

The weight of crop picked always varied according to the number of trusses present and it is quite clear that any effects of maleic hydrazide on cropping was due to the influence on the number of flower trusses produced in the previous autumn, rather than to any carry over effect on the vigour of the plants. The effect of treatment on cropping depended largely on the variety. In Redgauntlet treatment increased the crop above the control value, although in only one case was this increase significant. At the other extreme it caused a severe reduction in crop at all levels in Cambridge Favourite, and a moderate reduction in two out of the three levels applied to Cambridge Vigour. Talisman showed slight reductions in yield, which reached a significant level in only one treatment (1000 ppm applied on 22nd June and 22nd July).

DISCUSSION

When assessing the results of this experiment it is essential to bear in mind the economic considerations which control the relationship between the attention given to a plantation and the possible gain in crop resulting from any additional expenditure on labour and materials.

Thus in a comparison of the yields obtained from plants treated with maleic hydrazide with that obtained from the controls, the latter value should be regarded as the maximum to be obtained by runner control since all primary runners were removed by hand at frequent intervals. Under these conditions a slight reduction in yield after treatment with maleic hydrazide may be more than balanced by the saving in labour for hand or mechanical removal of runners. To be of any practical value, chemical control must be achieved by not more than two spray applications during the summer. As the results of Table IV for runner initiation show this requirement was met except perhaps in the variety Redgauntlet, in which runner control only just reached an acceptable level.

For the two varieties Talisman and Redgauntlet, the crop produced in the following year was reasonably close to that produced by the control plants. In Vigour and especially Favourite the depression in crop yield after treatment suggests that in these varieties maleic hydrazide might cause an unacceptable reduction in yield. It should be noted that the original planting material of the two latter varieties was of rather poor quality and the severe effect of maleic hydrazide on them may have been the result of applying it to plants which were not sufficiently well established at the time of treatment. This explanation seems more likely than to suggest that maleic hydrazide had a direct effect on flower initiation in these two varieties. Papers by Denisen (1953) and Thompson (1961) show that if applied at the time of flower initiation maleic hydrazide may reduce its level. In this experiment however the last spray treatment was applied about a month before initiation is believed to have started, and there was no suggestion, in either variety that treatment had interfered with flower initiation.

These and earlier results (Thompson 1960) suggest that maleic hydrazide may be an effective means of controlling runner production in maiden plantations of strawberries grown on the single row system. In view of the narrowness of the concentration range between runner control and severe depression of growth of the parent plant, more work is needed to give additional information on optimum doses for a number of varieties under as wide a range of conditions as possible.

To make its use a practical proposition it is probably essential that maleic hydrazide should be used in combination with a weedkiller in order to control both weeds and runners. Recent results using simazine (Chappell and Bower 1959; Rahn and Fieldhouse 1960), 2,4-D (Hemphill 1951), or 2,4-DES (British Weed Control Council 1958) as means of controlling weeds in strawberries suggest that this aim may be attainable. In which case it may be possible to dispense entirely with all summer cultivations of maiden strawberry plantations and rely on a combined spray of weedkiller and runner inhibitor, followed in late autumn by a single cultivation to destroy surviving weeds and runners.

Acknowledgements

The author wishes to thank Messrs. Fisons Fertilizers Ltd. who kindly supplied the maleic hydrazide used in these esperiments.

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substituted urea herbicides have been tested by Mr. Sutherland but, at the doses used, fenuron, diuron and neburon either caused crop injury or failed to control weeds, so that in general the substituted ureas do not appear to be as promising as the substituted triazines for weed control in raspberries. Work on blackcurrents has not been as extensive as on raspberries but the results with simazine have been equally promising. Mr. Holloway has applied this chemical at 2½ and 5 lb/ac for two successive seasons without any adverse effect and promising

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results have also been obtained in Northern Ireland. Blackcurrants may be even more sensitive to monuron than raspberries and at East Malling 10 lb/ac killed a number of the bushes while even 5 lb/ac caused a significant reduction in yield.

In general the results suggest, more strongly than at any previous British Weed Control Conference that the future for the use of herbicides in fruit crops is full of promise. Since soft fruits were first cultivated, we have looked upon hand cultivation as the ideal method of controlling weeds, but in several experiments better results have been obtained where hoeing has been replaced by chemical treatment. Higher yields of better quality raspberry canes, for example, were obtained by Sutherland and Stephens where simazine replaced hand cultivation in a cane nursery bed and in blackcurrants at Loughgall, a higher yield has been obtained where dalapon and other chemicals have been used since 1956 to suppress weeds than on plots kept clean by hoeing. It seems likely that these higher yields are due to the absence of root injury, which is unavoidable when crops with surface roots are cultivated mechanically.

Discussion on preceding papers on Fruit crops.

Mr. P. A. Thompson. I should like to make a few comments which are relevant to the relationship between root growth and sensitivity to simazine in strawberry. There are two main points to consider, first the sensitivity of strawberry plants in the spring and, second, the relatively high resistance of young runner plants. Although the greatest amount of root tissue is formed in late summer and autumn, roots formed at this time are large adventitious roots whose main function is anchorage and the storage of carbohydrates mainly as starch. In the spring, on the other hand, the roots formed are small feeding roots and it is likely that the sensitivity of the plant to simazine at this time is due to the constant production of these small roots which afford much opportunity for uptake of simazine from the upper layers of the soil. The first roots formed by runners are also mainly for anchorage and probably are not very efficient absorptive organs, so that it is not until secondary feeding roots are established in the lower soil levels that the runner becomes self-supporting. This probably explains how the roots of the runners are able to pass through a surface layer of simazine treated soil without the plants being injured by the chemical.

Mr. F. A. Roach. Our observations and trials in the S.E. region support what has been said about the value of simazine for use in fruit crops. We too have found that low doses of simazine show promise for the selective control of weeds in strawberry runner beds.

With regard to the use of dalapon to control grass along rows of apple tres, we find a difference in the control achieved according to the season. In the dry year of 1959 results were very promising but the reverse was the case in the wet season of 1960. For the control of grass round fruit trees simazine appears to work best in wet years and dalapon in dry years.

Mr. W. T. Cowan. I should like to ask why there has been this dismissal of the substituted urea compounds. We have done a considerable amount of work on munuron and although less is known about diuron I think there is much more promise for these compounds than the papers suggest. This year for example, diuron has given very good results in a number of trials on raspberries. Doses of 2 and 4 lb/ac have given very good control of annual weeds without damaging the crop and this compound would appear a promising alternative to simazine.

Mr. D. W. Robinson. I hope I did not give the impression that the substituted ureas should be prematurely rejected. I said that the triazines in general, appeared to hold more promise that the substituted ureas and I think this is a fair comment. I also said, however, that there is a strong case for occasionally varying the herbicide used and it will obviously be necessary to evaluate all the groups of residual herbicides.

Mr. J. Sutherland. In our own experiments we have used monuron on a larger scale than diuron and in 1959, a very dry year, monuron gave better weed control than diuron. The main drawback with both chemicals is that, at low doses, groundsel, Veronica spp. and fumitory are not controlled whereas low doses of simazine have given excellent control of these species. Duiron might, however, have an important part to play in the possible rotation of herbicided in order to combat accumulation in the soil or to prevent the build-up of resistant species of weeds.

Dr. D van Staalduine. We did some experiments comparing the effects of spring application of simazine on Madame Moutot strawberries and found that the plants were more susceptible to diuron than to simazine. On the other hand we think that diuron has possibilities in some other fruit crops.

Mr. A. L. Abel. As a complete layman I should like to ask the horticulturalists whether the planting distances used in practice are determined by the necessity of cultivating for control of weeds. Will the arrival of these newer selective herbicides allow closer planting distances and so increase production per acre?

Mr. David Lowe (Chairman) Answering this question as a grower, my first reaction is that there would not be much difference. Many experiments have been carried out on the spacing of fruit crops and I think that the factors limiting yield have generally been plant nutrients, light or some other such factor rather than the spacings necessary to permit control of weeds.

Mr. F. A. Roach. In aswer to Mr. Abel's question I think that, in the South East, chemical control of weeds in strawberries might enable the row width to be reduced from 3 ft to 2 ft 6 in. with a consequent increase in yield, but this would not necessarily apply to other areas.

Mr. G. A. Toulson. As an agriculturalist I am distrubed to learn of the rather free use of monuron as a herbicide in horticulture, particularly where double and treble cropping systems are employed. In a series of trials in Wales it has been shown that even adose of 1½ lb/ac of monuron applied as a pre-emergence treatment gave a complete kill of swedes and kale as well as controlling the weeds. Yet in horticulture it seems possible to apply 2-3 lb/ac of monuron yearly to some crops without affecting the crops that follow. How is the build up of residues of this most toxic herbicide being avoided in practice?

Mr. D. W. Robinson. There is, of course, a danger of build-up following repeated application of high doses of monuron, but the results presented today are only reports of experiments. No official recommendation is made at present for the use of monuron on fruit crops and no such recommendation would be made for doses likely to result in accumulation from repeated annual application.

Mr. W. T. Cowan. May I confirm that growers have been using monuron on asparagus and there is not the slightest danger from annual application of 2 lb/ac.

obtained equivalent to 2, 1, 0.5, 0.25, 0.125 and 0.0625 lb/ac mixed uniformly with the surface 2 in. of soil. Two replicate series for each crop were set up in plastic pots, seed sown, the pots sub-irrigated, and after an arbitary period which varied for the different crops, numbers and fresh weights of surviving plants were recorded.

RESULTS

Three field tests were carried out during 1959 with simazine, propazine, trietazine and atrazine applied at rates of 0, 0.25, 0.5 and 1 lb/ac. The details were as follows:

1. Five crops. Begun in March when the soil moisture status was high. Approximately 1 in. rain fell during the first three weeks after spraying.
2. Twelve crops. Begun early July during a very dry period. Approximately 0.5 in. irrigation was given 10 days after spraying, and this was repeated 20 and 25 days after spraying.
3. Twelve crops. Begun at end of July, Although 0.15 in. rain fell immediately after spraying, dry weather followed and 0.5 in. irrigation was given 10 days after spraying.

From the records which were taken, the effect of each chemical on each crop has been summarised by assigning a rating on a scale of 0-10. A rating of 0 indicates absence of any injury from 1 lb per acre, whilst a rating of 10 denotes complete kill at 0.25 lb/ac. These data are shown in Table I.

TABLE I. COMPARATIVE RESPONSE OF VEGETABLE CROPS TO PRE-EMERGENCE APPLICATIONS OF FOUR TRIAZINES

Injury rating

(0 = no effect at 1 lb/ac; 10 = complete kill at 0.25 lb/ac)

Test number	Simazine			Propazine			Trietazine			Atrazine		
	1	2	3	1	2	3	1	2	3	1	2	3
Radish	-	5	6	-	5	6	-	4	4	-	7	9
Cabbage	-	8	9	-	7	8	-	4	5	-	8	10
Lettuce	-	10	10	-	9	10	-	7	8	-	10	10
Spinach	-	6	9	-	8	9	-	4	6	-	8	10
Beet (globe)	-	10	10	-	9	9	-	6	8	-	9	10
Onion	8	6	7	7	6	8	5	1	4	9	8	8
Carrot	9	7	10	4	4	4	6	3	5	9	9	10
Parsley	-	6	6	-	3	0	-	0	0	-	6	6
Parsnip	1	4	5	0	1	0	0	0	0	2	4	6
Pea	3	3	4	3	1	0	1	0	0	6	4	6
Broad bean	4	0	2	3	0	2	0	0	0	5	3	6
Dwarf Fr. bean	-	6	7	-	5	7	-	1	3	-	6	8

The glasshouse test was carried out as already described, and from the dosage -response curves based on fresh weight of surviving plants, estimates were obtained of the amount of herbicide, in lb/ac mixed with 2 in. soil, required to reduce fresh weight to 50 per cent of that of the control. The values obtained for eight crops are shown in Table II.

TABLE II. COMPARATIVE SUSCEPTIBILITY OF VEGETABLE CROPS TO FOUR TRIAZINES INCORPORATED IN THE SOIL

Dose (lb/ac mixed with 2 in. soil) required to reduce fresh weight by 50 per cent.

	Simazine	Propazine	Trietazine	Atrazine
Radish	0.20	0.14	0.61	0.17
Cabbage	0.19	0.17	0.44	0.08
Lettuce	0.08	0.18	0.31	< 0.06
Beet (globe)	0.15	0.12	0.30	0.08
Onion	0.13	0.15	0.56	0.07
Carrot	0.12	1.50	0.62	0.14
Parsley	0.40	> 2.00	> 2.00	0.40
Parsnip	> 2.00	> 2.00	> 2.00	1.18

Pea, broad bean and dwarf French bean were included in the test, but as only small numbers of plants were involved, response curves have not been constructed. It appeared that for pea, a dilution of simazine, propazine or atrazine equivalent to approximately 0.5 lb/ac was required to reduce fresh weight by 50 per cent while for trietazine the value was 1.4 lb. Dwarf French bean was rather more susceptible than pea, while broad bean was more tolerant and required the equivalent of more than 1 lb of each compound per acre. Injury symptoms were very slow to appear in this crop, however, and it is possible that the tolerance was overestimated. Good data were not obtained for spinach, but it appeared that this crop was approximately as susceptible as radish.

DISCUSSION

The data of Tables I and II show that in general, atrazine was the most phytotoxic of the four compounds and trietazine the least, whilst simazine and propazine were intermediate. Information from the field tests and from other experiments indicates that the four compounds can be placed in the same order in respect of kill of annual weeds. The data suggest that atrazine does not have any potential use as a pre-emergence herbicide in the crops tested.

Radish, cabbage, lettuce, spinach, beet and onion were susceptible to all four compounds at doses required for weed control. The results for the other crops listed in Table I, however, suggest that pre-emergence use of particular compounds might be feasible, and these possibilities are considered briefly below.

Carrot. In all the tests, carrot was very susceptible to simazine and atrazine, but showed a much greater degree of tolerance to propazine; it was also the only crop to be injured more by trietazine than by propazine. In a replicated trial, propazine at 0.5 lb/ac caused some stunting and chlorisis without affecting

yield, but at 1 lb/ac yield was reduced. Nevertheless, propazine appears to hold some promise if used at doses of no more than 0.5 lb/ac.
Parsley. This crop showed some tolerance to propazine and trietazine, and both would seem to merit further testing. In a replicated trial, propazine at 0.5 lb/ac caused some chlorosis but did not affect yield.
Parsnip. Both field and glasshouse tests confirmed the impression that this crop possesses some tolerance to simazine. In replicated field trials, 0.5 lb/ac caused temporary chlorosis, but at 1 lb/ac reduction in yield sometimes occurred. As suggested by the results in Table I, propazine appears to be more selective than simazine in this crop and in replicated trials, propazine 0.5 lb/ac has given good weed control without crop damage. Trietazine would also appear worthy of further examination.
Pea. The results indicate that the inherent tolerance of this crop to simazine, propazine and atrazine is not very great, but suggest that the possible use of trietazine should be investigated further.
Broad bean.. In replicated trials at Wellesbourne, good weed control without crop damage has been obtained with simazine applied at 0.5-0.75 lb/ac. With 1 lb/ac, extensive marginal necrosis of the leaves has sometimes occurred, whilst with 1.5 lb/ac there were reductions in yield. Considerable variation in degree of injury has been encountered under different rainfall conditions and on plots treated with 1-1.5 lb/ac it has been noticable that of two adjacent plants, one might be killed or severly damaged, whilst the other remained unaffected. These observations suggest that the inherent tolerance to simazine is not very great, and that depth of sowing and rapidity of establishment may be critical. Nevertheless, at doses of 0.5-0.75 lb/ac the use of simazine would seem to be feasible on the particular soil involved. Trietazine has had no observable effect on broad beans even when applied at 2 lb/ac, and the possiblities of this herbicide are being further investigated.
Dwarf French bean. This crop appears to be more susceptible than either pea or broad bean, and only trietazine would seem to be worthy of further testing.

It is concluded from this work that there are only limited possibilities for the use of the four triazines for weed control in the twelve crops investivated Atrazine did not show sufficient selectivity in any crop. Simazine appears to hold promise only in broad bean. Propazine appears to be worthy of further examination in carrot, parsnip and parsley, whilst trietazine appears to merit testing in parsnip, parsley and the three large-seeded legumes.

Acknowledgements

We are grateful to Fisons Pest Control Limited for making available the herbicides used in this work.

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USE OF PRE-EMERGENCE HERBICIDES FOR VEGETABLES IN THE UNITED STATES

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Summary: The use of pre-emergence herbicides on vegetables in the United States has expanded rapidly in the past ten years. Among the materials that are widely applied are dinoseb, chlorpropham, CDAA, CDEC, simazine, atrazine, monuron, NPA and TCA. Some of these are much more important in America than in Europe because of differences in the relative importance of various crops and weeds, especially annual grasses. There are several promising new herbicides which are of special interest to vegetable growers. Two that have received considerable attention are amiben and dimethyl 2,3,5,6-tetrachloroterephthalate.

INTRODUCTION

Chemical weed control in vegetables in the United States received its first real stimulus with the discovery about 1943 of the selective action of certain petroleum oils on carrots and other umbelliferous crops. To be sure, there had been earlier attempts at selective weed control but this was the first use that was widely adopted by growers. During the next few years the major developments were with other post-emergence herbicides including sulphuric acid and potassium cyanate for onions and dinitro compounds for peas. The growth regulators were widely tested for vegetables but very few lasting uses developed.

Starting in the late 1940's and expanding rapidly in the 1950's the idea of pre-emergence treatments evolved and at present by far the majority of the herbicides used on vegetables in the United States are of the pre-emergence type. In the early work (Anon, 1958, 1960) contact materials such as potassium cyanate, oils and PCP received a great deal of attention but with the development of residual types of herbicides the interest in strictly contact pre-emergence treatments has largely disappeared. However, it should be emphasized that an important feature of some presently used residual materials is the contact action obtained on early germinating weeds by 'delayed pre-emergence' or 'at emergence' treatments. It must be pointed out that most of the pre-emergence herbicides have been used in the more humid areas of the country. There have been many difficulties in adapting pre-emergence herbicides to the extensive furrow-irrigated vegetable areas of the south west.

THE WEED PROBLEM

Weeds are as serious a problem in American vegetable crops as they are in British vegetables. High labour costs and actual shortage of hand labour has forced the growers to mechanize production and harvesting. Therefore, effective herbicides are readily accepted by the vegetable grower.

In spite of the general similarity in the need for selective herbicides in Great Britain and America there are tremendous differences in the specific problems. The relative importance of various weeds and crops should be emphasized. There are only a few areas in the United States where the climate is similar to that of the British Isles. Much of the country has a continental climate which is more suitable to the production of warm weather crops. For example, outdoor tomatoes, melons and sweet potatoes are major vegetable crops in the United States, while brussels sprouts and cauliflower are quite minor. In Great Britain the reverse is true. The relative importance of weed species is likewise greatly influenced by climate. The high summer temperatures that are characteristic of much of the United States encourage many annual grasses including Setaria, Digitaria and Echinochloa species. Annual grasses make up the great majority of the weeds in many areas, and thus there has been a great deal of emphasis on the development of new chemicals that are effective for their control. The broadleaved weed problem is also different, Portulaca oleracea and Amaranthus species being especially serious. In contrast, some of your most important weeds such as Urtica urens and Poa annua (Roberts, 1959-60) are unknown to most American vegetable growers and even Stellaria media is a problem in only certain of the dooler climatic areas.

These differences in the problems we face have been pointed out to give a better understanding of the remarks which follow. Having new seen some of the weeds and vegetable crops in Great Britain, I can better appreciate the reasons for the failure of some of our best herbicides under your conditions and likewise the minor importance in America of some of the treatments that have proved effective in Great Britain.

In view of this contrasting situation in the two countries, it is hoped that the information presented here will be used with discretion. An attempt has been made to summarise the important commercial uses of pre-emergence herbicides and mention is made of some of the promising results with new materials. It is hoped that from this information some ideas may be obtained which will be of value in the development of selective herbicides for vegetables grown in Great Britain.

PRE-EMERGENCE HERBICIDES IN COMMERCIAL USE ON VEGETABLES

Dinoseb is generally recommended in the humid regions of the country for pre-emergence treatment of all kinds of beans and in many of these areas it has been widely used. In the north-eastern part of the United States dinoseb is often applied as a pre-emergence treatment on peas and potatoes. It has also been used in mixtures with chlorpropham as described below.

Chlorpropham (CIPC). This herbicide is used extensively for control of weeds in onions grown on organic soils at almost all stages of crop growth, but late season treatments are applied as directed sprays or as granulars. The rates of application are high (4 to 8 lb/ac) because of the tremendous adsorption of this chemical by organic soils. It is especially effective on Polygonum spp. and Portulaca oleracea. However, at the high doses used and by making the early season applications after many weeds have emerged, several other species are killed by contact action. Chlorpropham is often used in combination with CDAA on organic soils to improve the control of annual grasses and Amaranthus spp. On mineral soils chlorpropham is commonly recommended in the north central and north eastern states for use on onions grown from sets or transplants, but it has not proved satisfactory in the winter onion areas of Texas for either field-seeded or transplanted onions.

Extensive areas of peppermint and spearmint grown on organic soils in the mid-west are being treated just before emergence with a mixture of chlorpropham and dinoseb. This same mixture has sometimes been recommended for beans, but has not been widely used.

For several years chlorpropham was in quite general use on the east coast for weed control in several vegetable crops grown for greens and salads. It has now been replaced to a considerable extent by CDEC although mixtures of the two are being suggested in some places. Carrots have shown a high degree of tolerance to pre-emergence treatments of chlorpropham but use on this crop has not been developed due to the excellent results obtained with selective soils.

Propham (IPC). Because of rapid decomposition and vapour loss at high soil temperatures, chlorpropham has largely replaced this herbicide in the United States. The only important use on a vegetable crop is as a pre-planting treatment for control of *Avena fatua* in peas in the north west.

CDAA. This herbicide is especially effective on annual grasses and thus has been much more widely used in America than in northern Europe. It is one of the main herbicides now applied to onions grown on organic soils. For this purpose it is used either alone or in mixtures with chlorpropham. Treatments may be made before emergence or, at later stages of growth, either as directed sprays or as regular applications.

Where annual grasses are the major problem, CDAA has also been used on sweet corn on all except the sandier soils. A new use that has just been approved is a granular application on tomatoes immediately after transplanting.

CDEC. This herbicide is now used by many vegetable growers especially on the east coast. Annual grasses and certain broadleaved weeds including *Lamium* spp. are controlled in a number of vegetable crops grown for greens and salads. Results have been good in some areas and poor or unpredictable in others. The reasons for this are not clear but a light sprinkler irrigation after treatment is considered helpful.

EPTC. This is a relatively new herbicide but commercial use is developing on beans (*Phaseolus vulgaris* only) and on potatoes for control of annual grasses and suppression on *Cyperus* spp. Because of vapour losses it must be incorporated in the soil immediately after application.

Simazine and atrazine. These materials are generally recommended for sweet corn and have been well accepted by growers. Simazine also has given good results in experimental work on asparagus, but it has not been approved for treatment of this crop.

Monuron and diuron. Monuron is the principal herbicide that is applied to asparagus. Either one or two treatments are made per season at rates varying from 1 to 3 lb/ac depending on the soil type. Results have been good almost everywhere. Diuron is being tried for certain crops because of the greater depth protection afforded by its lower solubility and greater adsorption by the soil. It has been recommended for peppermint in the north west and for a few other crops in limited areas.

TCA. The largest single use of this material on vegetables probably has been for the pre-emergence control of annual grasses in red beets. The crop is highly tolerant and results have been good in areas where grasses are the major weed problem. Another specialised use has developed in the mid-west on field-seeded tomatoes where a mixture of TCA and potassium cyanate have given good results. The potassium cyanate gives contact kill of early germinating weeds, while the TCA is effective as a residual treatment for annual grasses. Potatoes and cabbage have also been treated to a limited extent with TCA.

NPA. (Naphthylphthalamic acid) This herbicide is well tolerated by musk-melons, watermelons and cucumbers both before and after emergence. However, it is only effective when applied before weed emergence so treatments are usually made just after seeding or transplanting in the field. Use of NPA on these crops is not general in the United States, but has developed in some areas.

PROMISING NEW PRE-EMERGENCE HERBICIDES

Amiben and dinoben. These closely related compounds are highly active on a broad spectrum of annual weeds, yet there are certain crops which show excellent tolerance. Carrots, peas, sweet potatoes, most kinds of beans and certain Cucurbita species (C. pepo, C.moschata and C. maxima) have good resistance to amiben. By using the granular formulations additional crop selectivity has been obtained. These formulations of amiben have given promising results on trans-planted brassicas and tomatoes on medium to heavy soils. Dinoben is slightly less active than amiben but for lettuce and strawberries there are indications, that it may be safe, whereas amiben may not.

Dimethyl 2,3,5,6-tetrachloroterephthalate (Dacthal). This is a material with very low water solubility (less than 0.5 ppm) that is strongly adsorbed by soil colloids. It is highly selective in its action on both weeds and crops. Stellaria media, Chenopodium album and several annual grasses are especially sensitive, but Polygonum and Brassica species and many other weeds are highly resistant. Excellent selective control of susceptible weeds has been reported on a number of vegetable crops including the brassicas, carrots, beans, potatoes, peas, onions, tomatoes and sweet potatoes. Since it is practically inactive as a foliar spray, it has also given good results on a number of transplanted crops for control of germinating weeds. Performance has been best on the lighter soil types while on organic soils it is so strongly adsorbed that its use is not practical.

Other pre-emergence herbicides. A large number of new chemicals are being investigated in the United States. Among these are the new triazines, EPTC analogues, diphenylacetonitriles and 2,6-dichlorobenzonitrile. Some of these have given encouraging results, but the information is still too limited to draw any conclusions as to their possible place in vegetable weed control.

PROMISING NEW POST-EMERGANCE HERBICIDES

Although this report has been concerned primarily with pre-emergence herbi-cides, it would be unfortunate if we overlooked a new group of post-emergence materials that are of particular interest to vegetable growers. These are the phenylamides being tested under the names Karsil, Dicryl and Solan. They are active primarily as foliar sprays and are all selective on carrots, celery, parsley and parsnips. Karsil and Dicryl are more active that Solan and have therefore received most attention on these crops. Compared with the selective oils now in use they are more effective on Chenopodium album and less effective on annual grasses. Solan is selective on established tomatoes and has been suggested for trial on potatoes.

CONCLUSIONS

It is hoped that this paper will give some idea of the present use of pre-emergence herbicides in the United States. Our climate, crops and weeds are quite different, but perhaps some of the things we have learned will suggest new lines of research. With the large number of promising new chemicals that appear each year the future is certainly bright.

Acknowledgements

The author is grateful for much unpublished information used in preparing this paper which was kindly supplied by the following individuals: L.L. L. L. Danielson, H. H. Harris, E. S. Haygood, D. D. Hemphill, R. D. Sweet, W. Weber, W. C. McConnell and S. R. McLane.

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OBSERVATION STUDIES ON THE USE OF RESIDUAL HERBICIDES ON ANEMONES DURING 1958-59 AND 1959-60

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Summary: Trials using residual herbicides in controlling weeds in anemones were carried out in the 1958-59 and 1959-60 seasons. Weather conditions were vastly different in these two seasons, the summer of 1958 being wet and that of 1959 very dry. This served to show the inconsistency of simazine which gave good control of weeds in the first year at 2 lb/ac, but checked growth of the anemones, and comparatively poor weed control in the second year. Monuron was more consistent but less efficient than simazine and at 2 lb/ac some check to the anemones also occurred. Chlorpropham at rates above 1 lb/ac also caused considerable damage, but when applied at ½ lb/ac mixed with fenuron at 1 lb/ac weed control appeared fairly good with little damage to the anemones. PCP at 4½ lb/ac was included for comparison in the second year and showed good initial weed control, but the effect was not so lasting as with the residual herbicides.

INTRODUCTION

The first of the trials using residual herbicides was carried out in 1958-59 and repeated with some modifications the following year. Both trials are reported on separately as the climatic conditions in the two seasons were vastly different giving contrasting results.

Anemone corms are planted at a depth of 2-3 in. and the emergence period is about 14 days, conditions which are well suited to weed control by the residual type of herbicide. Fairly extensive trials have already been done using contact herbicides and these have been described in the 2nd, 3rd and 4th Annual Reports of work at Rosewarne Experimental Horticulture Station.

I. TREATMENTS IN THE 1958-59 SEASON

METHODS AND MATERIALS

The materials used were chlorpropham at 1, 2 and 4 lb/ac, fenuron at ½, 1 and 2 lb/ac, simazine at ½, 1 and 2 lb/ac, chlorpropham at 2 lb and fenuron at ½ lb/ac, and hand weeding as control. There were 4 replications of each treatment. The sprays were applied on 15th July during hot dry conditions, the 2/3 cm grade corms having been planted 6 days previously on 9th July. The plot size was 20 ft x 6 ft containing a 4 row bed of anemones at 12 in. apart with a bordering footpath also included in the sprayed area. The dry weather at the time of application did not last and the succeeding weeks were extremely wet.

RESULTS

Weed counts were made at intervals taking a random sq ft sample on each plot. Table I shows the average numbers at each count for the 4 replications of each treatment.

TABLE I. WEED COUNTS

	Number of days after spraying - 1959 season							
Treatments	15	17	21	23	27	30	35	41
CIPC at 1 lb	14	14	15	15	18	18	14	18
CIPC at 2 lb	22	33	17	24	23	26	17	20
CIPC at 4 lb	12	12	11	10	13	12	13	11
Fenuron at ½ lb	30	29	29	36	37	34	39	35
Fenuron at 1 lb	14	10	8	22	17	21	26	23
Fenuron at 2 lb	12	14	11	9	9	11	19	15
Monuron at ½ lb	10	13	9	8	15	11	13	15
Monuron at 1 lb	9	7	6	7	5	6	8	6
Monuron at 2 lb	13	10	3	4	4	4	3	4
Simazine at ½ lb	12	10	6	4	7	8	6	7
Simazine at 1 lb	11	4	3	2	3	4	3	3
Simazine at 2 lb	12	7	2	2	2	2	1	< 1
CIPC + Fenuron	12	9	10	13	19	15	15	16
Control	26	31	36	41	40	39	38	Not Counted

In this wet season simazine and monuron had the greatest effect on weed growth, the population growing progressively less at each count except in the case of monuron at ½ lb/ac. Where the applications were at 2 lb/ac no hand weeding was found necessary throughout the whole of the season. Simazine was more effective than monuron. Chlorpropham was somewhat disappointing giving only fair control at the higher dose and poor control at the lower doses. Fenuron appeared to have little effect at all.

As soon as crop emergence commenced on 24th July it was evident that chlorpropham at 4 lb/ac had caused damage. The anemone leaves appeared stunted, curled and yellow and the vigour of the plants was well behind that of other plots. Damage was also apparent but not so severe with chlorpropham at 2 lb/ac and also with the chlorpropham/fenuron mixture. Growth with all other treatments appeared normal until mid-October when plants on the simazine 2 lb/ac plot began to show signs of a check in growth. There were no unhealthy symptoms other than this slowing of growth in comparison with other healthy plants, and later in February and March normal and more vigorous growth was resumed. There was a similar but very slight check with monuron at 2 lb/ac. None of the other treatments apart from chlorpropham had any adverse effect.

The yields of blooms are set out in Table II as marketable flowers cropped in successive 4 week periods with the totals or marketable flowers and the totals of all flowers cropped.

TABLE II. YIELDS OF MARKETABLE FLOWERS FOR EACH MONTH

(Totals of the 4 replicates)

Month ending:	4/10/ 1958	1/11/ 1958	29/11 1958	27/12/ 1958	24/1/ 1959	21/2/ 1959	21/3/ 1959	Total	Total of all flowers cropped
CIPC at ½ lb	-	11	23	7	26	21	115	203	1276
CIPC at 2 lb	-	11	21	9	25	22	192	280	1365
CIPC at 4 lb	1	8	13	2	19	32	103	178	913
Fenuron at ½ lb	-	12	19	4	27	32	123	217	1369
Fenuron at 1 lb	2	24	31	8	41	44	164	314	1476
Fenuron at 2 lb	-	4	34	6	40	43	162	289	1470
Monuron at ½ lb	-	18	33	14	32	26	107	230	1428
Monuron at 1 lb	2	18	40	21	58	62	172	373	1662
Monuron at 2 lb	-	9	27	9	39	46	216	346	1471
Simazine at ½ lb	3	26	46	7	66	57	214	419	1602
Simazine at 1 lb	1	13	23	13	38	17	115	220	1375
Simazine at 2 lb	-	7	8	6	33	26	145	225	946
CIPC at 2 lb) Fenuron at ½ lb)	-	12	27	8	16	13	79	155	1354
Control	1	14	28	6	27	27	101	204	1428

The highest yield of marketable blooms came from the ½ lb/ac simazine plots followed by the 1 lb/ac monuron plots although the latter gave the highest total yield. Where damage at commencement of growth had occurred with chlorpropham yields were correspondingly low. Relatively low yields were also obtained on the hand weeded plot. In this case the first weeding had been left to a late date and removal of the large weeds had disturbed the anemones. Where growth was checked by simazine and monuron cropping was reduced during the latter months of 1958 but increased again with the improvement of growth in the following spring.

II. TREATMENTS IN THE 1959-60 SEASON

METHODS AND MATERIALS

Following the results of the previous season the treatments were modified omitting those obviously detrimental and of little value. The treatments were chlorpropham at ½ lb plus fenuron at 1 lb/ac, monuron at 1 lb/ac and ½ lb/ac, simazine at 1 lb and ½ lb/ac, PCP at 4½ lb/ac, and two controls (i) minimum hand-weeding removing larger weeds only and (ii) frequent careful hand-weeding keeping plots as clean as possible.

PCP although not a residual herbicide was included as being standard commercial practice and the two types of hand-weeding were an attempt to study the degree to which anemones are damaged by soil disturbance. The corms were planted on 22nd June and the chemical treatments applied on 2nd July - 10 days later in very dry conditions which persisted throughout the summer.

More work is necessary in the case of anemones to find the most suitable residual herbicide and to establish the critical dose where maximum weed control and minimum damage to the anemones occurs. This can be made more complicated by differing climatic conditions, to which anemones may react in any case. However these plants will soon indicate if there is any substance within reach of leaves or roots that is disagreeable to them.

TRIALS OF HERBICIDES ON NARCISSUS AND TULIP BEDS, 1958-60

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Summary: In field trials with herbicides on narcissus and tulip crops chlorpropham was used alone, in mixtures with fenuron or diuron, and following application of contact herbicides at the pre-emergence period of bulb growth. Post-emergence applications of chlorpropham were also tested at different developmental stages of the crops. The effectiveness of comparative treatments varied within the limits of weed cover and doses in relation to times of application, and under different weather conditions in two consecutive years. No programme gave completely satisfactory results. Herbicidal effects diminished in late April, or early May, and weed growth generally became vigorous before July. Difficulties increased when narcissus bulbs were not lifted annually. On observation plots diquat gave promise for pre-emergence use, while for post-emergence use neither diuron nor simazine gave adequate control of weeds at dosage levels of crop tolerance.

INTRODUCTION

Though the control of weeds in bulb crops by herbicides has become commercial practice, much remains to be done to obtain the essential information about the tolerance of weeds and crops to those herbicides which have seemed promising in preliminary tests. For the major bulb crops this is especially true of chlorpropham which, despite its limitations, seems likely for some time to occupy an important place in the bulb growers' weed control programme.

Since chlorpropham became available for bulb crops in Britain in 1957, its limitations have had a marked influence upon the role assigned to it in alternative herbicide programmes, particularly as a result of its failure to control Senecio vulgaris (groundsel) and Matricaria maritima ssp. inodora (mayweed). To overcome this difficulty three methods have been advocated; (a) early pre-emergence application on a clean tilth, (b) mixture with a residual additive to which groundsel and mayweed are not resistant, and (c) following or mixed with a pre-emergence contact herbicide.

Used either alone or as a mixture with fenuron, another residual herbicide, chlorpropham has given good results in post-emergence applications, though Wood and Howick (1958) observed crop injury, and Dutch workers (1958) drew attention to some factors influencing bulb crop susceptibility.

In continuing field trials at the two N.A.A.S. experimental centres responsible for investigating bulb growing problems - Kirton E. H. F., Lincs. and Rosewarne E. H. S. Cornwall - an attempt has been made to collect data having a bearing on existing controversial issues, with a view to making the best use of available herbicides while conducting preliminary tests with new materials.

The recent voluntary exclusion of sodium arsenite for herbicidal use has made specific reference to that material in some respects irrelevant, except as a standard for comparison.

TABLE I. TREATMENT MEAN YIELDS AND PER CENT INCREASES FROM 300 BULB/PLOTS

Narcissus 'King Alfred', 12 cm offsets. Wt/plot planted 28 lb
Layout: 8 treatments: 3 randomised blocks
Spray volume: All sprays applied at 100 gal/ac

Dates of spray applications	1958-59	1959-60
(a) Early pre-emergence	28 October	22 October
(b) Late pre-emergence	24 November	11 November
(c) Post-emergence	2 March	25 January

Treatment (lb/ac)				Mean yield	Per cent
	Pre-emergence		Post-emergence	lb/plot	increase
(a)	Chlorpropham/fenuron	2.5	-	70.3	151
(a)	Chlorpropham	4	-	66.0	136
(a)	Chlorpropham	2	+ Chlorpropham 2	67.6	141
(b)	Sodium arsenite	9.8	+ Chlorpropham 2	70.6	152
(b)	PCP	10.5	+ Chlorpropham 2	67.0	140
	Handweeded			66.3	137
	Kept clean by cultivation			66.0	136
	Unweeded			60.2	115
			General mean	66.75	138

S.E. 1.95 (14 d.f.) = 2.92 per cent of general mean
sig. diff. between mean yields 4.76 lb at P = 0.01, 3.43 lb at P = 0.05

The yields from treated plots were all significantly higher than those from unweeded plots. Judged visually, on all the plots receiving an early application of chlorpropham groundsel was plentiful, and the plots receiving a contact herbicide + chlorpropham were the cleanest. There was no indication that fenuron had caused injury to the crop.

Trials of post-emergence applications of chlorpropham on narcissus and tulip 1959-60

With the aim of studying the conditions under which crop injury occurs, chlorporpham at 2 lb/ac was applied at four stages of crop growth and the weather conditions prevailing before and after treatment were recorded. The results are given in Table II.

TABLE II. DATES OF TREATMENT, GROWTH STAGES, AND CROP YIELDS

Narcissus 'King Alfred' 14 cm 55 bulbs/plot. Wt planted 126 oz
Tulip 'Rose Copland' 10 cm 50 bulbs/plot. Wt planted 35 oz
Layout: 5 x 5 Latin squares
Spray volume: All sprays applied at 100 gal/ac
Herbicide: Chlorpropham 2 lb/ac

Date of application	Growth stage	Mean yield oz	Per cent increase
Narcissus			
25 January	Leaves 2 in. high	236	87
23 February	Leaves 5 in. high	234	86
23 March	Immediately pre-flowering	234	86
20 April	After flowering	236	87
Control Untreated	-	222	76
S.E.5.12 (12 d.f.) = 2.20 per cent General mean Sig.diff. 9.8 oz at P = 0.01		232.4	84.4
Tulip			
2 February	Folded leaf	98	179
10 March	Cupped leaf	81	131
20 April	Full leaf	87	150
18 May	After flowering	92	163
Control Untreated	-	76	119
S.E.9.84 (12 d.f.) = 11.33 per cent General mean Sig.diff. 13.5 oz at P = 0.05		86.8	148.5

At the commencement of the trial the plots were cultivated so that the herbicide could be applied on a clean tilth. There was no visible injury to narcissus, but the untreated plots became weedy. With tulip, however, slight differences in vigour were evident. Dwarfing of flower stems did not occur, but differences in growth followed the sequence ultimately shown by yields. The critical stage for tulip injury appeared to be during the period of rapid growth commencing at the cupped leaf stage, before elongation of the flower stem commenced; but it was not possible to interpret differences in accordance with temperatures, or humidity, and the soil was moist at all times.

Observation plots 1959-60

In 1959 a number of herbicides were applied as post-emergence treatments on tulip beds on 23rd March when weather conditions were favourable and monuron 0.5 lb/ac, simazine 0.5 lb/ac, chlorpropham 2 lb/ac and a chlorpropham 2 lb/fenuron 0.5 lb/ac mixture all caused crop injury. It was observed however that fenuron at 0.5 lb/ac had the least injurious effect and only caused a slight difference in the colour of the crop foliage, while chlorpropham inhibited the growth of the flower stems.

The following however, seemed promising for further trial on narcissus and tulip.

Diquat 2 lb/ac. Late pre-emergence application gave favourable results.
Chlorpropham 2 lb/diuron 0.5 lb/ac mixture, for early pre-emergence use.
Simazine 0.5 lb/ac early pre-emergence, followed by chlorpropham 2 lb/ac applied late pre-emergence.
PCP 5 lb/ac late pre-emergence followed by chlorpropham 2 lb/ac early post-emergence.

DISCUSSION

Chlorpropham appears to be a very useful herbicide for controlling weeds in the major bulb crops. Its merits are ease of handling, and effectiveness at winter temperatures, but its limitations should not be overlooked. It is clear that on narcissus and tulip crops, both fenuron and diuron are useful as additives to chlorpropham. The use of an efficient contact herbicide is generally more impressive through speedier visual effect. All herbicides however have limitations, and the aim in using a contact herbicide first must surely be to obtain a weed-free bed, failing which chlorpropham will not give good results. PCP has maintained its position for this purpose, and diquat also promises to be useful. For pre-emergence use chlorpropham mixtures appear to be more efficient than chlorpropham alone, where certain weeds are present; to advocate the use of chlorpropham alone is perhaps no longer tenable.

Concerning crop tolerance, no injury to tulips by chlorpropham at 2 lb/ac has yet occurred in trials if the spray has been applied before the leaves unfurled, nor to narcissus before the leaves separated at a height of approximately 2 in.

Though herbicide programmes for bulb crops are now generally used, the period of weed control is not sufficiently extended. During approximately two months before crops are harvested the grower is unable to find a remedy other than hoeing, or hand weeding. On established bulb beds of narcissus the difficulty continues through summer and early autumn. It is desirable that such a problem should not be overlooked.

Acknowledgments

We desire to express our thanks to the A.R.C. Unit of Experimental Agronomy, Oxford, to manufacturers who have supplied materials and given information about their products, and especially to Miss B. Upsall, our recorder.

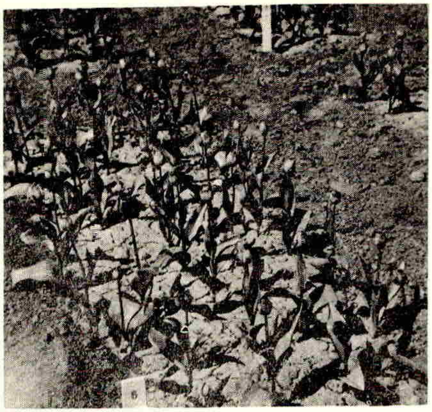

FIGURE 1. CHLORPROPHAM AT 4 LB/AC APPLIED PRE-EMERGENCE IN TULIPS. PHOTOGRAPH TAKEN IN MAY.

FIGURE 2. THE SIMILAR EFFECT ON NARCISSUS FLOWERS OF DALAPON AT 10 LB/AC AND TCA AT 20 LB/AC APPLIED IN SEPT 1958. PHOTOGRAPH TAKEN IN APRIL 1960.

At doses needed to control Agropyron repens neither chemical is considered safe.

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THE USE OF TRIAZINE HERBICIDES IN HORTICULTURE, ESPECIALLY ON FLOWERS AND ORNAMENTALS

A. Gast
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Summary: Some possibilities of practical use of triazine herbicides in horticulture are described. In nurseries and established ornamental shrubs, as well as in roses, simazine may be used very safely. Propazine is advised for further experimentation, especially in conifers. Among bulbs, gladiolus may be treated with simazine but not with propazine. Tulips, narcissus and crocus are more sensitive and there are contradictory results. A method is described to keep fallow land weed-free with simazine before Chrysanthemums are planted. Because of their short residual effects methyl-mercapto triazines may offer better possibilities for horticultural use than for instance simazine or propazine.

INTRODUCTION

The practical use of triazine herbicides, particularly of simazine and atrazine in agriculture (e.g. maize), viticulture and in nurseries of woody plants has become more and more common during recent years and is now very widespread in the above mentioned crops. In numerous publications the properties of the triazines and the results of experiments have been described, so that a basic knowledge about the possibilities of application may be supposed to be known.

In field crops and viticulture the world-wide practical use has brought a lot of experience, so that the possibilities of application can be defined today very accurately. In horticulture we find a more complicated situation, only for a limited number of ornamentals do we dispose of sufficient experience to recommend a general use of triazines. For quite a number of horticultural crops we are still in the phase of experimentation. According to the experience gained so far there are two main reasons which are limiting the practical use of triazines in these crops. Most of the horticulturally cultivated plants possess only a weak physiological resistance to triazines, and the long residual effect of triazines in the soil is in some cases a disadvantage, because a following sensitive crop may be damaged. In order to reduce this danger only small amounts of the herbicide can be used, but in that way also the limits of sufficient weed control are reached.

ORNAMENTAL SHRUBS, ROSES

The treatment of ornamental shrubs and roses with simazine normally presents no difficulties, because simazine is kept back in the surface layers of the soil and there is no phytotoxic effect on the deeper roots.

In nurseries and established plantations of ornamental shrubs simazine has a wide field of practical use. The results of numerous experiments in different countries have shown that among the various species of woody ornamentals there are only few which are very sensitive and may show phytotoxic symptoms or damage. Among the more sensitive ones we find representatives of the following families:

Saxifragaceae: Deutzia gracilis, some Ribes species
Oleaceae: Syringa, Ligustrum, Fraxinus and among the
Rosaceae: Spiraea bumalda.
Larix decidua seems to be more sensitive than other conifers.

An experiment with simazine, propazine and trietazine in a new plantation of conifers and broad leaved trees, which was started in 1958 and is still going on, showed an interesting difference of sensitivity to the triazines used. Propazine in comparison with simazine has a higher degree of safety in conifers but a poorer one in the broad leaved trees. Trietazine was very safe in both categories but the herbicidal effect was distinctly lower compared with the corresponding amounts of simazine and propazine, so that trietazine may be dropped in further experimental work. Further work with propazine in conifers, however, is strongly recommended.

Roses present a very advantageous field of application for simazine and a treatment with the above mentioned herbicide normally presents no risk. In an experiment which was started in 1957 (in the first spring after plantation) and where treatments have been repeated every year until now, only one variety Mme. Pierre S. du Pont has shown injury, whereas New York, Friedrich Schwarz, Comtesse Vandal have remained without any damage. During the first summer after the application Mme. du Pont showed chlorosis and a growth depression. Now, after four treatments with 3 lb/ac simazine, the plants are stunted but not chlorotic.

Another experiment was carried out on young plants which were grafted the previous year. In 1956 the varieties Puricelli, New York, Comtesse Vandal, Spek's Yellow, Friedrich Schwarz, Marakesch, Mme. Pierre S. du Pont, Ville de Saverne were grafted on the rootstock Rosa laxa. During the following winter the young plants were covered with soil and in spring 1957, after the removal of the protecting soil layer, the herbicidal treatment was carried out on bare ground at 5, 3 and 1 lb/ac simazine. In applying the treatment no precautions were taken to avoid a contact of the herbicide with the plants, which already showed the first leaves. The development of the young grafts in the next growing season was quite normal and they showed no phytotoxic effects. Mme. du Pont also remained uninjured in this experiment. The herbicidal effect of simazine at all doses was good to excellent.

Chemical weed control in one year old grafts is of great practical value, because the mechanical removal of the weeds must be executed very carefully to avoid damage to the young shoots.

In an experiment with the variety Spek's Yellow simazine was applied to the regions of the roots with a soil sterilant injector. The injected amount of simazine corresponded to a surface treatment at 3 lb/ac, in another plot the same amount was applied as a surface treatment for comparison. Neither treatment produced any sign of phytotoxicity and it may be concluded that roses possess a certain natural resistance to simazine so that the good results obtained with this chemical are not only based on a "positional selectivity".

A special experiment with three varieties of rootstocks showed obvious differences in resistance to simazine. The rootstocks tested, Rosa canina Bröghs, Rosa laxa, and Rosa multiflora, were planted on April 15, 1958, and treated a month later with 15, 7.5, 5 and 2.5 lb/ac simazine. The results are summarized in Table I.

TABLE I. RESISTANCE OF ROSE ROOTSTOCKS TO SIMAZINE

0 = no damage
\+ = slight chlorosis on all plants
++ = slight chlorosis and/or necrosis on all plants
+++ = heavy chlorosis and/or necrosis on all plants

Inspection date	Variety	Simazine lb/ac			
		15	7.5	5	2.5
30. 6.1958	R. can Bröghs	0	0	0	0
22. 8.1958		0	0	0	0
13.10.1958		0	0	0	0
30. 6.1958	R. laxa	++	+	0	0
22. 8.1958		++ (stunting)	0	0	0
13.10.1958		0	0	0	0
30. 6.1958	R. multiflora	++ - +++	++	+	+
22. 8.1958		++ (3 plants dead)	0	0	0
13.10.1958		stunting	0	0	0

It is interesting to note that with R. Bröghs and R. laxa at all doses and with R. multiflora from 7.5 lb/ac downwards, some plants were distinctly better developed at the end of the season than untreated plants. The disappearance of the phytotoxic symptoms during the growing season indicates that roses are able to metabolize the absorbed simazine into innocuous compounds. Among the three tested varieties R. multiflora is obviously more sensitive than R. laxa and R. Bröghs, while R. Bröghs is the most resistant.

BULBS

Much experimental work has been done on this subject especially in England and the Netherlands. It has been found that Tulips, Narcissus and Crocus are rather sensitive to simazine and this chemical can only be used at low doses. At doses above 100 g/ac damage is likely to occur but even at this low dose simazine can give a useful degree of weed control especially when used in combination with chlorpropham.

Gladiolus appears to be more resistant and in a number of experiments these plants have been treated with up to 5 lb/ac simazine. In rainy summers this dose has caused some damage, but never sufficient to kill the plants. These experiments showed also that among the diverse varieties of Gladiolus there are considerable differences in sensitivity, and it may be that this is the reason for some of the cases of damage which have occurred in the practical use of simazine. In a special experiment to evaluate differences in sensitivity the following varieties were tested: Alfred Nobel, Sans Souci, Aranjuez, Harry Grant, Johann Strauss, Joe Wagenar, Atlantic, Picardy, Paul Rubens, Neu Europa, Han van Megeren, Poppy Day, General Eisenhower, Mansoer.

The most sensitive of these were Aranjuez and Mansoer, which showed obvious damage at 2 lb/ac and light symptoms of phytotoxicity even at 1 lb/ac.

Neu Europa, Atlantic and Poppy Day were injured only at 3 lb/ac, Joe Wagenar was very resistant, showing practically no symptoms even at 5 lb/ac while the rest of the above-mentioned varieties showed distinct damage at 5 lb/ac, but not at 3 lb.

These results indicate that simazine may be used for Gladiolus, but for the most sensitive varieties it is advisable to use relatively low rates of application.

FLOWERS AND PERENNIAL ORNAMENTALS

Whereas the treatment of annual flowers with simazine is practically impossible, there are some positive results in established perennials.

In 1958 the following species were treated:

with simazine 2 lb/ac: Solidago, Iberis, Papaver, Kniphofia, Delphinium, Helenium, Sedum, Paeonia

with simazine 1 lb/ac: Hemerocallis, Sedum, Iris

All the treated plants behaved like the untreated ones until the end of the growing season.

In an established Delphinium plantation some plots were treated at 5, 3, 2 and 1 lb/ac simazine (first treatment May 7, 1958) and the plants developed quite normally. After flowering they were cut down completely at the end of July in order to stimulate new growth and the second shoots also showed no differences in comparison with the plants in the check plot. After repetition of the same treatments in 1959 there were still no signs of damages.

There is a special problem connected with the culture of Chrysanthemums which are only brought into the open during summer. From spring until the moment the Chrysanthemums are planted out the soil cannot be used for other crops but it should remain free of weeds. On May 19, 1958, various plots were treated with 1 and 2 lb/ac simazine. In one part of the area Chrysanthemums were planted out immediately after the treatment without pots, in the other part they remained in pots. All the plants were damaged to some extent but good results were obtained when the pots with the plants were not brought into the treated area until July. None of the tested varieties Etoile de Valence, Louvrier, Jean Cot, Calypso, Gerbes d'Or showed any injury and the weed control was excellent.

RESIDUAL PROBLEMS

As already mentioned one of the limiting factors for the use of triazines in horticulture is their long lasting effect and the possibility of residues effecting following crops. Simazine and propazine, which can be used as selective herbicides in carrots and celery, are particularly liable to cause damage to following sensitive crops.

We therefore tested the possibilities of planting flowers in plots previously treated with these chemicals.

Experiment 1

May 29, 1957: Treatment with simazine and propazine at 4 and 2 lb/ac

Autumn 1957: Ploughing

Spring 1958: Planting of Zinnia (var. Scarlet Flame, Golden Dawn) and Aster (Herz von Frankreich, Chinaaster)

Result: Normal development of all plants.

Experiment 2

May 7, 1958: Treatment with simazine and propazine at 5, 3, 2, 1 lb/ac (experiment on Gladiolus)

Sept. 1958: Planting of Viola tricolor, Myosotis and Cheiranthus

Results in April 1959:

Simazine at all doses:	Test plants normal	
Propazine 5 lb/ac	Viola	normal
	Cheiranthus	normal
	Myosotis	15 per cent kill; remaining plants stunted
Propazine 3 lb/ac	Viola	normal
	Cheiranthus	normal
	Myosotis	stunted
Propazine 2 and 1 lb/ac	All plants normal	

The experiments show that Viola tricolor and Cheiranthus are particularly suitable for planting after a crop which was treated with simazine or propazine.

FUTURE DEVELOPMENT

In the course of the last few months we have tested various methyl-mercapto triazines which have a very rapid herbicidal action and a short residual effect. They show too, a distinct selectivity in carrots. Though there are as yet no results available on the effects of these compounds on flowers there is hope that some horticultural problems will find a better solution using these new chemicals, owing to their short residual action.

Discussion of preceding five papers

Mr. G. D. Lockie. I should like to make a comment on diquat, which has been mentioned several times. We have had very satisfactory practical experience with this chemical at Fernhurst when applied as a pre-emergence or pre-planting treatment. It gives a quick kill of weeds, is broken down rapidly in the soil and can be of great value in speeding up recropping, especially when conditions are too wet for cultivation. It also shows promise as a 'chemical hoe' for a wide range of vegetables, flowers and shrubs.

Dr. R. Pfeiffer. Can simazine be used at low doses in a perennial flower border in winter?

Dr. G. W. Ivens. Experiments with simazine suggest that doses up to about 1 lb/ac can be used safely on established plants of a number of perennial flowers such as Chrysanthemum maximum, Delphinium, Peony and Scabious but a great deal more experimental work is needed before any general recommendation can be made.

Mr. Paul Bracey. In the last year or so we have been concentrating on improving the safety margin of residual herbicides by developing special formulations which tend to keep the chemicals in the upper layers of the soil. The danger of building up toxic residues of such compounds as chlorpropham, fenuron and 2,4-DES does not appear to be very great as large areas have now been treated with these chemicals and up to 5 treatments have been applied without causing any damage to subsequent crops.

Mr. R. W. Sidwell. Dr. Gast's work shows variation in susceptibility of rose rootstocks to simazine but I am not clear as to the effect of rootstocks on the susceptibility of the scion varieties. In fact, in the studies on scion varieties no mention of rootstock is made. Would Dr. Gast please clarify the position?

Dr. A. Gast. In the rose experiments all roses were grafted on Rosa canina.

Mr. J. D. Whitwell. Have full investigations of the possibility of adverse side effects from the use of simazine been made? For example, in South Devon an asparagus crop treated with 2 lb/ac of simazine become smothered with Solanum nigrum. I realise that an alternative chemical can be used but these side effects often appear suddenly. I should also like to comment on the ineffectiveness of simazine in a dry year. When this chemical was applied under fruit trees in autumn 1959 at Pershore Horticultural Institute better control of grass was obtained with a volume rate of 1000 gal/ac than with 100 gal/ac.

With reference to roses, simazine applied at 2 lb/ac at a site in Devon has caused damage to the Floribunda variety Fashion.

Mr. H. A. Roberts. It is quite true that, if the same herbicide is used year after year on the same land, the tolerant species tend to increase. We have shown this in asparagus beds in the instance of Veronica persica and monuron. The answer, I think, is rotation of herbicides as advocated by Mr. A. L. Abel at a previous conference.

Dr. F. H. Feekes. I should like to point out that the chlorpropham treatments shown in Mr. Wood's slides were applied too late in the season. The leaves of the tulips should still be closed when chlorpropham is applied so that no chemical gets into the tube formed by the leaf blade. In Holland we consider diuron and other substituted ureas too dangerous to be used in bulbs, especially in tulips.

Mr. J. Wood. I am pleased to learn that Dr. Feekes agrees that chlorpropham can injure bulb crops when applied at the wrong time. We have stressed that point repeatedly.

Concerning the value of diuron as an additive, we have not had sufficient experience of using chlorpropham/diuron mixtures. A single pre-emergence application was promising but two pre-emergence applications appear to be near the margin of crop tolerance, especially with tulips, and we shall await the results of further experiments before making any recommendation.

SESSION 8

Chairman: Professor A. H. Bunting.

NEW HERBICIDES FOR THE CONTROL OF WILD OATS

FACTORS AFFECTING THE SELECTIVITY OF BARBAN FOR THE CONTROL OF AVENA FATUA IN WHEAT & BARLEY

R. K. Pfeiffer, C. Baker and H. M. Holmes

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Summary: Timing of barban application proved the most critical factor. The best results were obtained when the main flush of wild oats were sprayed at the 1-2½ leaf stage. In practice the period during which spraying gave a good control lasted, on average, 10-14 days. Some experimental results are presented showing how crop competition appears to assist barban in reducing a wild oat infestation. Differences in the tolerance of barley varieties to barban are described.

If applied in one spray, 2,3,6-TBA and 2,4-D markedly reduce the activity of barban on cereal crops and wild oats. MCPB does not produce this effect; MCPA and mecoprop gave intermediate antagonistic activity to barban. 2,3,6-TBA and 2,4-D also antagonise barban if applied up to 4 days before but not if applied several days after barban.

At the tentatively recommended barban rates, optimum performance was obtained at spray volumes between 10 and 30 gallons per acre. Comparisons between spraying vertically and at an angle of 45° showed no differences in wild oat control or crop safety. The same was found when comparing a single application with split applications of barban.

INTRODUCTION

Following the first publications by Hopkins and Hoffman (1959) on specific selective properties of 4-chloro-2-butynyl-N-(3-chlorophenyl) carbamate (barban) against Avena fatua in cereals, investigations by the authors started in 1959 to assess the value of this new herbicide under British conditions. A substantial part of the investigations was directed towards a study of the factors found or suspected to influence reliability and selectivity of barban. This paper presents the results so far obtained in a very condensed form, because of the strict limitation of space. As the different aspects are not necessarily related to each other the results are briefly discussed under the separate headings.

METHODS AND MATERIALS

Chemical: Barban formulated by Spencer Chemical Company (1.18 lb per Imperial gallon emulsifiable concentrate)*

Design of experiments: All greenhouse and field experiments were replicated. On most factors under investigation several field trials on different fields were carried out using basically the same design.

Assessment and presentation: Wherever possible assessments were made either by counting wild oats, or by measuring the grain yield or fresh weights of plants. The method of "Blind Scoring" of effects was used in some experiments, all of which were replicated and included the herbicide in a range of treatments.

RESULTS

Time of Application and Susceptible Growth Stages of Wild Oats

Previous work by Hopkins and Hoffman (1959) had shown wild oats to be most susceptible at the $1\frac{1}{4}$ to $2\frac{1}{2}$ leaf stage. This observation was confirmed by the authors in 1959.

Following this finding two questions of practical importance arose and the authors directed their work towards throwing some light on these problems. Considering the fairly long period over which wild oats can germinate in certain seasons, what is the relative importance of wild oats emerging after the first flush have been sprayed with barban, and over what period can barban be successfully sprayed in practice?

On the first aspect two experiments were carried out in which assessments were made of the proportion of seed contributed by wild oat plants emerging at increasing intervals after sowing the crop. The results are presented in the following two tables, which show (a) that 75-79 per cent of the wild oats emerged during a fairly short period - this first flush of plants contributed 95 per cent of the wild oat seed formed by all plants and (b) a marked reduction in the number of spikelets per plant emerging at later dates - this effect can be ascribed to the influence of crop competition.

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* As "Carbyne"

TABLE I. NUMBER OF SPIKELETS PRODUCED BY WILD OATS IN RELATION TO TIME OF EMERGENCE

Site 1 - Spring wheat

Sowing date - March 7th, 1960.

Date of Emergence	No. of plants	Total no. of spikelets	No. of spikelets/ plant
Before 3rd April	38	1434	37.7
April 3rd - 12th	104	1746	16.8
April 13th - 19th	20	100	5.0
April 20th - 26th	16	42	2.6
April 27th - May 4th	8	2	0.2
May 5th - 11th	1	10	10.0

Site 2 - Spring barley

Sowing date - March 3rd, 1960.

Date of emergence			
Before April 1st	42	950	22.6
April 1st - 7th	126	1072	8.5
April 8th - 14th	16	87	5.4
April 15th - 21st	9	5	0.6
April 22nd - 28th	2	1	0.5

These results were obtained in 1960 when the weather was very dry during the germination period. The authors are well aware that the emergence pattern and subsequent growth are likely to be influenced by variation in weather conditions.

On the second aspect - the period during which successful control can be obtained - ten field experiments (5 on spring barley, and 5 on spring wheat) were carried out in which barban at 4 oz/ac on wheat and 6 oz/ac on barley was sprayed at intervals of 3 days. The spraying period which covered about a month started when the wild oats were mainly at the ½-1 leaf stage and continued until the 4-4½ leaf stage was reached.

The final **result** averaging all experiments is shown in Figure 1.

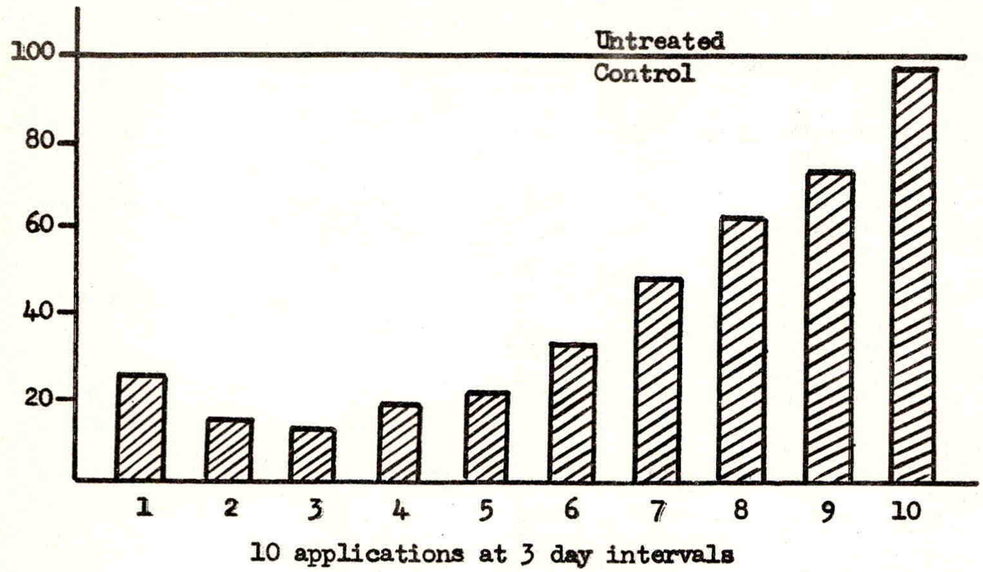

FIG. 1. PERCENTAGE OF WILD OATS REMAINING AFTER SPRAYING AT DIFFERENT TIMES. MEAN OF 10 EXPERIMENTS

The results showed that spraying should be done when the main flush of wild oats had emerged but before many had passed the 2½ leaf stage. The detailed results show over what period spraying gave acceptable results (at least 80 per cent control) at each site. This is summarised as follows:-

Number of experiments	Spraying period giving 80 per cent control
2	20 days and over
2	15-19 days
4	10-14 days
2	less than 10 days

Crop Competition and Dose

The degree of competition offered by the crop was found to be of considerable importance. The authors originally thought that a highly competitive crop directly assists and increases the activity of barban on wild oats by reducing the light intensity around the weed and thus slowing down breakdown of the herbicide.

A complex field experiment was carried out in which the degree of crop competition was varied by using different seed rates of barley cross-drilled with cultivated oats (var. Victory). This experiment showed a) that increasing the seed rate of barley (without spraying barban) itself led to a significant reduction in weight of oat plants per unit area, and b) that barban spraying superimposed over each seed rate of barley gave a constant relative reduction of weight of oats of the order of 80 per cent. (see Figure 2).

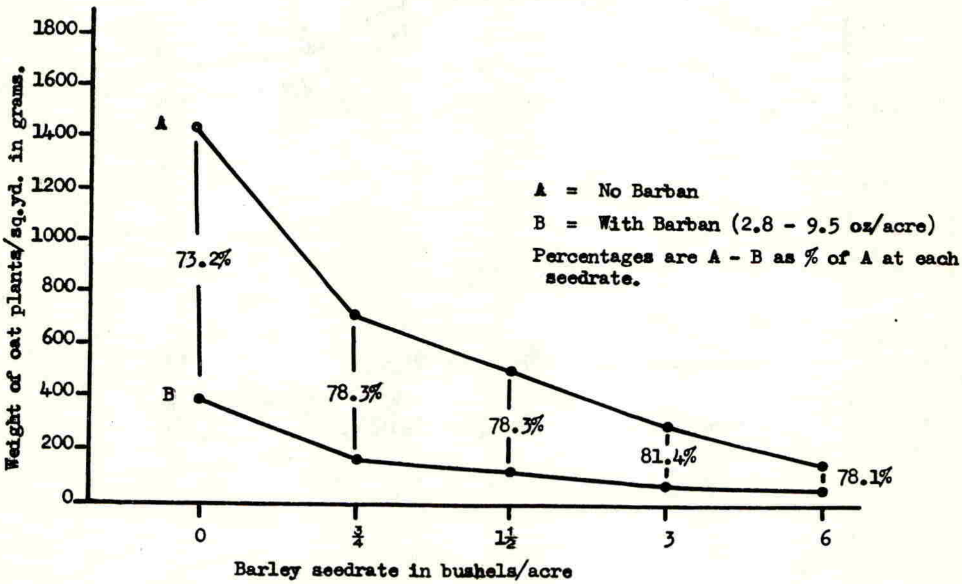

FIG. 2. EFFECT OF BARLEY SEED-RATE ALONE AND BARLEY SEED-RATE PLUS BARBAN ON TOTAL WEIGHTS OF OAT PLANTS/SQ YD.

Weights taken end of July. Oat seed in milk stage.

This result, if reproduceable under more practical conditions, implies a) that on an evenly infested wild oat field a highly competitive crop has, even without barban, less wild oats per unit area at harvest time as compared with a poor crop on the same field, b) that a certain dose of barban on both these crops will control more or less the same percentage of wild oats which the crop allows to develop, and c) that crop competition and barban effect are independent and simply additive.

The choice of an optimum dose is accordingly closely linked with crop competition. The authors found consistently that a dose leading to some crop damage, even if only temporary, will result in a heavier infestation at harvest time than a somewhat lower, but completely safe dose (Figure 3). Such crop damage appears to reduce crop competition with an obviously poorer result.

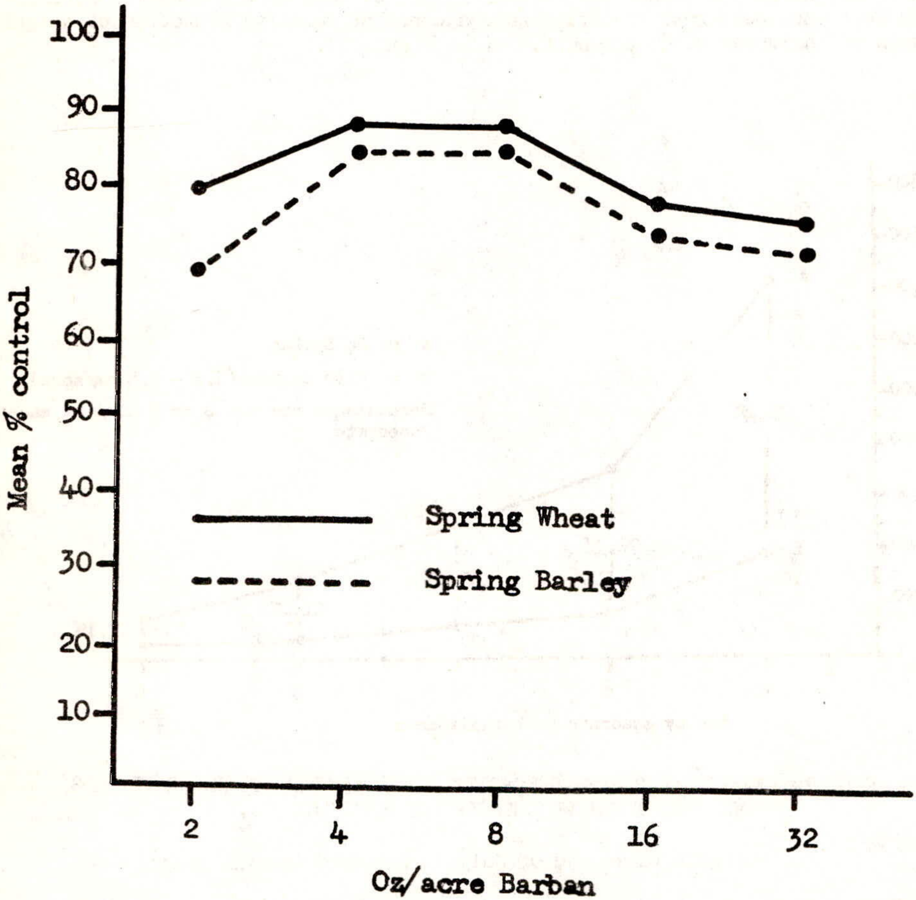

FIG. 3. MEAN PER CENT WILD OAT CONTROL IN 12 SPRING WHEAT AND 12 SPRING BARLEY EXPERIMENTS - 1959

(Based on estimates of size and number of wild oat panicles by three independent observers for each experiment.)

(78178)

Tolerance of Cereal Varieties to Barban

An analysis of 48 "logarithmic" barley experiments (42 in the U.K., 3 in Sweden and 3 in Denmark) in 1959 indicated marked differences in the tolerance of different barley varieties to barban. The variety Proctor showed considerably lower tolerance than the varieties Carlsberg, Rika, Herta, Ymer and certain Swedish 6-row barleys.

This observation was followed up by field and greenhouse investigations in 1960. 9 barley varieties were included in all 4 main experiments, the results of which are presented in Table II.

TABLE II: PER CENT GROWTH REDUCTION OF 9 BARLEY VARIETIES AFTER BARBAN TREATMENT

Degree of tolerance	Variety	Field expt 1960 16 oz	G/house expt 1960 8-32 oz	G/house expt 1960 8-32 oz	Field expt 1960 32 oz
(Group A)	Provost	93	55	41	100
	Proctor	90	64	50	100
low	Freja	94	53	53	80
	Plumage-Archer	92	48	31	80
(Group B)	Earl	67	41	13	20
	Rika	66	15	24	20
medium	Spratt-Archer	64	19	18	20
	Maythorpe	7	46	31	80
(Group C) high	Carlsberg II	22	19	18	0

These results confirm the observations made in 1959. The 9 barley varieties can accordingly be placed in 3 categories of tolerance. Varieties in category A are unlikely to tolerate the proposed practical barban doses (4-6 oz/ac), while the varieties in categories B and C are likely to be safe at these doses.

A number of other barley varieties were included in one or two of the experiments only. Subject to confirmation from further trials, these varieties can be tentatively placed in the 3 tolerance groups as follows:-

Group A (low tolerance) - Domen

Group B (medium tolerance) - Ingrid, Pallas, Nordgarden, Hillmarsh, Delta, Hafnia, Arva Kenia, Haisa II, Gateway Kenia, Gazelle, Volla, Herta, Vada, Ymer.

Group C (high tolerance) - Elsa, Swallow, Union, Topper, Pioneer.

The dose response curves for Proctor, Rika and wild oats assessed in a greenhouse experiment proved almost identical for Proctor and wild oats, while Rika showed much higher tolerance than either wild oats or Proctor. This result was confirmed by field observations, and it appears unlikely that selective control of wild oats will be practicable in Proctor barley or in varieties of a similar low tolerance. In a few isolated cases, however, even Proctor showed a high degree of tolerance to barban and good selective wild oat control was obtained. Research into the reasons for the variation in barban tolerance of barley under different environment conditions is in progress.

Evidence on the inherent nature of the tolerance factor was obtained from an experiment with Proctor, Rika and Proctor x Rika cross* (F.4 unselected). The cross gave an intermediate response between the clearly different responses of the parents.

Two types of barban toxicity have been observed on barley. The typical effect is a stunting of the main shoot but this may be preceded by a yellow mottling leading to "scorch". The occurrence of scorch depends on variety and environment as well as on dose. It is interesting to note that the relative susceptibility of Proctor (or Provost) and Rika (or Herta) to the scorch effect is the reverse of their sensitivity to the typical physiological barban stunting. The former follows the pattern as described by Hayes (1959) for the DDT susceptibility of these varieties. Details and implications of the authors' work on this aspect will be published elsewhere.

A field experiment in which barban was sprayed on 6 varieties of winter wheat did not give conclusive evidence of differences in tolerance between these varieties.

Interaction between barban and plant growth regulators

Several workers observed in 1959 an antagonistic interaction between barban and 2,4-D when applied in one spray. Such an admixture of 2,4-D considerably reduces the activity of barban. The authors tried to explain the mechanism of this antagonism by the assumption that a growth regulating substance, by temporarily inhibiting meristematic activity, does not enable barban to exert its specific phytotoxic effect in the growing point. Some of the barban was assumed to be detoxicated by the time normal meristematic activity started again. On the basis of this theory the authors expected to find marked antagonism even when the growth regulator was applied a few days before barban but not if it was applied several days later. A possible relationship was also expected between the degree of polar translocation of the hormone antagonist to the meristematic growing point and the subsequent reduction in barban activity. Thus, 2,3,6-trichlorobenzoic acid was expected to be the strongest, mecoprop and MCPB to be the weakest antagonists. The problem is of considerable practical interest in view of the possibility of a combined barban-hormone treatment.

The experimental results obtained can be summarised as follows:-

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* The authors gratefully acknowledge the help given by Dr. Bell, Director, Plant Breeding Institute, Cambridge.

Time of application of "hormone" antagonist

A greenhouse experiment (Oats and Barley) was carried out, using a standard barban treatment and treating the plants in addition with 2,4-D or 2,3,6-TBA at certain intervals before and after the barban treatment as well as applying the chemicals together at the same time. Figure 4 represents the overall result of this experiment. It shows reductions in barban activity even when the growth regulators were applied up to 4 days before barban but no antagonism (in actual fact some activation) is indicated when the growth regulator was applied after barban.

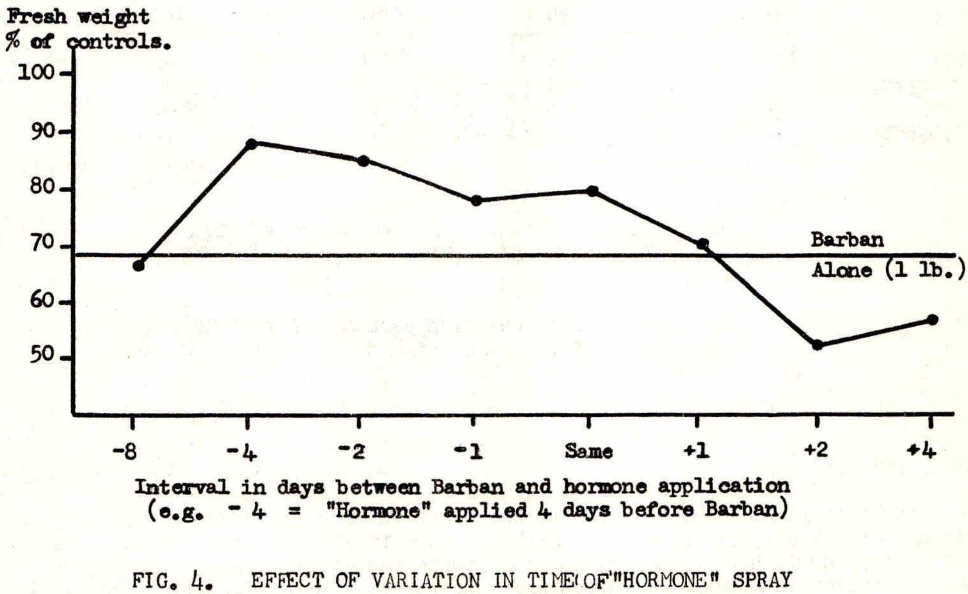

FIG. 4. EFFECT OF VARIATION IN TIME OF "HORMONE" SPRAY AS COMPARED WITH TIME OF BARBAN APPLICATION

Relative antagonistic activity of some commercial hormone herbicides

In this series of field experiments (wheat and barley infested with *Avena fatua*) several hormone weedkillers were applied mixed with barban and also as separate sprays applied one or two weeks after barban. The mean result of the 6 experiments is presented in table III. It shows a) 2,3,6-TBA/MCPA.to be the strongest antagonist followed by mecoprop and MCPA. A commercial formulation of MCPB (containing a small amount of MCPA) did not antagonise barban, and b) that none of the growth regulating herbicides antagonised barban if applied one week or later after barban.

TABLE III. RELATIVE ANTAGONISTIC ACTIVITY OF DIFFERENT GROWTH REGULATING HERBICIDES ON WILD OAT CONTROL

(Mean of 6 experiments)

+ indicates per cent increase in barban activity
- indicates per cent decrease in barban activity

Hormone dose oz/ac			Time and dose level of hormone application					
			With barban		1 week after		2 weeks after	
	High	Low	High	Low	High	Low	High	Low
MCPB*	18	9	+3	+1	0	0	-1	-4
mecoprop	38	19	-13	-17	-1	-3	-2	0
MCPA	20	10	-13	-12	+1	-4	-1	-2
2,3,6-TBA[x]	4	2	-55	-51	+1	+2	+1	-3

* the commercial formulation used contained MCPA which was applied at 3 oz/ac (high dose) and 1½ oz/ac (low dose)

the commercial formulation used contained MCPA which was applied at 12 oz/ac (high dose) and 6 oz/ac (low dose).

Spray Volume

Three standard field experiments were carried out in 1960 to confirm previous indications that the rate of barban needed to give a certain degree of wild oat control would have to be raised with increasing spray volume. In each of these experiments 4 doses of barban were sprayed in 3.3, 10, 30 and 90 gal/ac. Each experiment had 3 replications. Blind scoring for crop depression 2 months after treatment and for wild oat control (reduction in panicle number and size) at harvest time gave the results shown in Table IV.

TABLE IV: EFFECT OF SPRAY VOLUME ON THE TOXICITY OF BARBAN

(Average result of 3 field experiments)

Barban dose	Per cent reduction of cereal growth Gal/ac				Per Cent reduction of Wild oats Gal/ac			
	3.3	10	30	90	3.3	10	30	90
16 oz	56	63	63	42	66	57	68	73
8 oz	32	37	29	16	67	62	71	73
4 oz	16	20	20	10	64	77	71	65
2 oz					49	53	44	25
Average	35	40	37	23	61	62	64	59

This table shows that on wheat and barley at all doses, and on wild oats at 2 oz (the only critical dose) application at 90 gal/ac gave substantially lower activity than application at lower volumes, and that differences between 3.3, 10 and 30 gal/ac were small.

At the lower spray volumes, where a temporary check to crop growth was more marked, the degree of wild oat control appears to have been influenced by reduced crop competition. The data obtained from the lowest volume (3.3 gal/ac) are rather erratic owing to difficulties in applying the herbicide evenly at such low volumes. Similar variation occurred in results obtained in several aircraft experiments with barban.

Work on other factors

Directional Spraying Following a suggestion that spraying at an angle (nozzles turned to spray at 45^{o}) would give better coverage and therefore better results than vertical spraying, field experiments were carried out but failed to show any measurable difference.

Split application It was thought that splitting the standard dose of barban into two separate applications, at one or two week intervals, might increase the kill of wild oats obtained, by ensuring that all plants would be sprayed at a susceptible stage of growth. Four experiments were sprayed on sites infested with wild oats and percentage reduction in panicle size and number was estimated at harvest. The results obtained on average for all sites are shown in Table V

TABLE V. EFFECT OF SPLIT APPLICATION OF BARBAN

(Each figure is the mean of 8 plots)

Dose (oz/acre)*		Times of application	% Control of Wild oats	
Full Rate	Half Rate		Full Rate	Half Rate
6	3	Early	68	59
6	3	Medium	76	58
6	3	Late	75	63
4 + 2	2 + 1	Early + Medium	79	54
4 + 2	2 + 1	Early + Late	76	57
4	2	Early	54	41

* These doses were used in the two experiments on barley. Two-thirds of these doses were used in the experiments on spring wheat.

The figures show that no consistent advantage has been obtained to justify the additional cost of split application.

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THE EFFECT OF BARBAN ON THE YIELD OF WINTER WHEAT, SPRING WHEAT AND BARLEY

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Summary: The paper presents the results of 21 replicated field experiments. Barban was applied in all experiments at several doses and in most experiments at three to four different dates. The yield of winter wheat was significantly increased in wild oats or black grass infested sites when barban was applied between November and March. This crop, however, appears to pass through a rather sensitive development stage in March and in absence of wild oats slight yield depressions were observed when barban was applied at this stage. Best control of Avena fatua, Avena ludoviciana and Alopecurus myosuroides (blackgrass) was obtained in winter wheat by spraying barban between November and February.

Spring wheat and spring barley infested with Avena fatua frequently responded with a substantial yield increase to barban applied at 4 oz and 6 oz/ac respectively. Highest yields were obtained from spraying wild oats at the 1 to 1½ leaf stage, although the degree of control of wild oats was found to be somewhat better when spraying was carried out a few days later at the 1½-2½ leaf stage. In one barley experiment a yield increase of 20-30 per cent was found to occur at seven out of ten of the application dates, although wild oat control in this experiment reached 80 per cent at only one date of application.

INTRODUCTION

In 1960 a series of yield experiments were carried out to obtain evidence on a) the effect of barban on the yield of wild oat-free winter wheat and winter barley when applied at different development stages, b) the yield response of winter wheat (infested with Avena fatua, Avena ludoviciana, or Alopecurus myosuroides) to barban treatments, and c) the yield response of spring wheat and spring barley (different degrees of infestation with Avena fatua) to barban applied at different times.

The work included the first experiment with barban on Avena ludoviciana and Alopecurus myosuroides. Very good control of these important weeds in winter wheat was obtained from late autumn and winter treatments with 4-8 oz/ac. This interesting aspect is, however, not the objective of this paper and will be discussed elsewhere.

Details of results, including statistical data, for each individual yield experiment are presented as an appendix to this paper. The actual paper only contains simplified tables indicating the more important results.

METHODS AND MATERIALS

The evidence presented is based on 21 yield experiments (over 2000 individual yield plots) carried out on farms in east and central parts of England. The preparation used was an 11.8 per cent w/v commercial formulation of barban.* Each treatment in each experiment was replicated at least 4 times, and in most experiments 6-12 times. The experiments were laid out as simple randomised blocks or as split plots, the main plots being doses and sub plots time of application. The plot size varied between 12 and 20 sq yd. Barban was applied with an "Oxford sprayer" boom fitted to a knapsack sprayer. The spray volume was 19 gal/ac.

RESULTS

Effect of time of barban application on the yield of wild-oat-free winter wheat and winter barley

Three experiments were carried out on wild-oat-free winter wheat and one on winter barley (Details in appendix Expts: 1-4). Barban was applied at 2,4, 6 and 8 oz/ac at four dates of spraying from December 1959 until April 1960.

Winter barley (Expt: 4) showed no visual effects at any date or dose. The significance of the yield data from this uneven crop is low. Winter wheat proved sensitive, even to the proposed practical rate of 4 oz/ac, when treated in the middle of March. A significant yield reduction at this rate, however, only occurred in one of the three experiments (See Table I). No explanation has yet been found for the rather sensitive growth stage of winter wheat in March; further work on this aspect is planned.

TABLE I. MEAN YIELDS OF WINTER WHEAT AS PER CENT OF CONTROLS - WILD-OAT-FREE SITES

(Mean of 3 experiments)

Application Date	2 oz	4 oz	6 oz	8 oz
December (Second week)	97.2	103.2	100.9	98.3
January (Last week)	97.7	103.2	95.5	89.5
March (Third Week)	99.0	90.6	79.9	67.4
April (First week)	97.4	99.9	92.9	86.6

* As "Carbyne"

Effect of barban on wild oat or blackgrass infested winter wheat

Winter wheat infested with Avena fatua

The germination of Avena fatua in winter wheat spreads from autumn until April and its survival through the winter in eastern counties is largely dependant on the severity of the winter. The authors find it therefore very difficult to generalise from the evidence as to the best time for application, especially since the mild winter 1959/60 led to almost complete survival of autumn germinating Avena fatua and subsequent heavy infestations of winter wheat crops. A repetition of the experimental work therefore is necessary before firm recommendations can be made. The evidence available so far indicates that the best results (both for wild oat control and cereal yields) are obtained when barban is applied between November and March, and not later. The yield results obtained from application within this period are shown in table II (for details on other spraying dates see appendix Expts: 5-9).

TABLE II. RESULTS (AT 4 OZ ONLY) FROM 5 WINTER WHEAT EXPERIMENTS INFESTED WITH AVENA FATUA

Site	Application date	Yield as per cent of controls	Untreated yield cwt/ac	Yield increase cwt/ac	Degree of wild oat infestation
Eaton	Nov 17th	104.9	36.7	1.7	Medium
Eaton	Dec 17th	112.2	36.7	4.4	Medium
Didcot	Dec 17th	114.8	28.0	4.1	Heavy
Kingston	Dec 16th	123.3	35.4	8.3	Medium
Chesterford	March 22nd	108.8	41.8	3.7	Medium
Castle Camps	March 10th	110.1	19.6	2.0	Heavy

Winter wheat infested with Avena ludoviciana

One experiment near Oxford and one at Chesterford Park were carried out on almost pure stands of Avena ludoviciana. The results obtained with the 4 oz are summarised in table III. (For yield data from other doses see appendix Expts: 10 and 11).

TABLE III. RESULTS (AT 4 OZ ONLY) FROM 2 WINTER WHEAT EXPERIMENTS INFESTED WITH AVENA LUDOVICIANA

Site	Application date	Yield as per cent of controls	Untreated yield cwt/ac	Yield increase cwt/ac	Degree of wild oat infestation
East Hanney	Jan 12th	191.9	18.3	16.8	Heavy
Chesterford	Feb 5th	151.8	23.2	12.0	Heavy
Chesterford	March 15th	148.7	23.2	11.3	Heavy

All applications (winter on both sites, and March applications at Chesterford Park) gave a remarkable increase in yield which has not been reached in any *Avena fatua* infested crops. It must however be pointed out that the infestations were heavy. The yield depressions observed by March applications on wild-oat-free winter wheat were more than outweighed by the increase resulting from wild oat control, although a temporary depressing effect could be observed on the crop for several weeks following the spraying in March.

Winter wheat infested with blackgrass (Alopecurus myosuroides)

One yield experiment on winter wheat heavily infested with blackgrass was sprayed at 3 dates, November, December, and March. The stage of growth of the blackgrass in November and December was 1-1½ and 2½-3 leaves respectively. The late application gave only very limited control and was not harvested, while good control was obtained from the earlier applications. The yield results of the two earlier treatments with 4 oz are presented in Table IV (further details in the appendix Expt: 12). Experimental work on blackgrass control with barban will continue in the following season.

TABLE IV. RESULTS (AT 4 OZ ONLY) FROM ONE WINTER WHEAT EXPERIMENT INFESTED WITH BLACKGRASS (ALOPECURUS MYOSUROIDES)

Site	Application date	Yield as per cent of controls	Untreated yield cwt/ac	Yield increase cwt/ac	Degree of blackgrass infestation
Chalgrove	Nov. 20th	141.8	17.7	7.4	Heavy
Chalgrove	Dec. 17th	132.1	17.7	5.7	Heavy

Effect of time of application and barban dose on the yield of spring wheat and spring barley (different degrees of wild oat infestation)

Spring wheat

Five experiments were carried out on spring wheat with barban applied at three dates. Table V shows the results obtained at our tentatively recommended dose of 4 oz/ac. (For results with other doses see appendix Expts: 13-17).

TABLE V. SUMMARISED YIELD DATA FROM SPRING WHEAT EXPERIMENTS 1960 SPRAYED WITH 4 OZ BARBAN

Site	Yields as per cent of controls — Stage of wild oat (leaves)			Control Yield cwt/ac	Yield increase in cwt/ac			Wild oat infestation
	1-1½	1½-2½	More Than 2½		Time I	Time II	Time III	
Whittlesford	112.8	103.2	117.2	16.0	2.0	0.5	2.8	Very heavy (V.poor crop)
Hadstock	113.9	112.9	110.1	32.2	4.5	4.2	3.3	Medium
Haverhill	108.8	100.0	89.0	18.6	1.6	-	-2.1	Medium
Castle Camps I	103.4	102.1	98.1	18.5	0.6	0.4	-0.4	Very light
Castle Camps II	97.8	96.3	97.4	36.4	-0.8	-1.4	-1.0	No wild oats

The earlier treatment has in all except one experiment given the highest yield, probably due to a substantial reduction in competition from wild oats in early development stages of the crop. A slight reduction in yield is indicated in the wild-oat-free experiment at Castle Camps.

Spring barley

The results obtained from the tentatively recommended rate of 6 oz/ac at three dates of application are shown in the table VI (for details of all three rates see appendix Expts: 18-21).

TABLE VI. SUMMARISED YIELD DATA FROM SPRING BARLEY EXPERIMENTS 1960
SPRAYED WITH 6 OZ/AC BARBAN

Site	Yield as per cent of controls Stage of wild oat (leaves)			Control yield cwt/ac	Yield increase in cwt/ac			Wild oat infestation
	1-1½	1½-2½	More than 2½		Time I	Time II	Time III	
Boxworth	111.9	99.7	103.5	20.1	2.4		0.7	Heavy (poor crop)
Chesterford Park	124.6	105.9	110.6	18.7	4.6	1.1	1.9	Heavy (poor crop)
Castle Camps	111.5	110.1	104.0	34.5	4.0	3.5	1.4	Heavy
Chesterford	119.8	115.6	111.1	25.5	5.0	4.0	2.8	Heavy
Sewards End	130.0	120.7	125.2	26.2	7.8	5.4	6.6	Very heavy

The yield results with barley agree with those in spring wheat indicating the best yield response from early applications, in spite of the fact that wild oat control may be somewhat better when spraying is carried out a few days later. Figures 1 and 2 illustrate the relationship between wild oat control, barley yields, and application date. The first diagram shows the percentage of wild oats remaining, after an application of 6 oz of barban at ten dates of application at three day intervals, from the 1-4½ leaf stage, while the second diagram presents the barley yields obtained from each date of application in the same experiment.

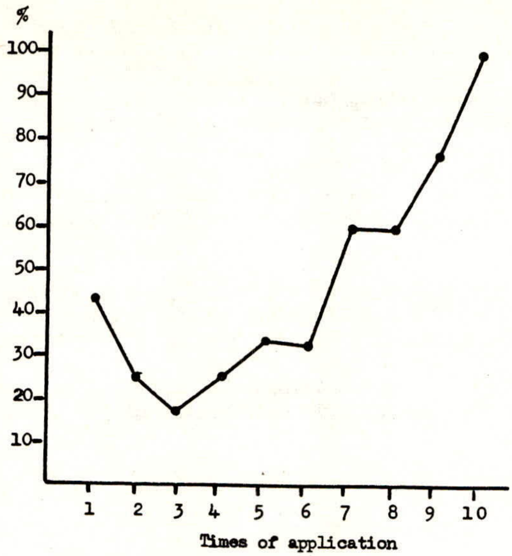

FIG. 1. PERCENTAGE OF WILD OATS SURVIVING IN BARLEY AFTER AN APPLICATION OF BARBAN

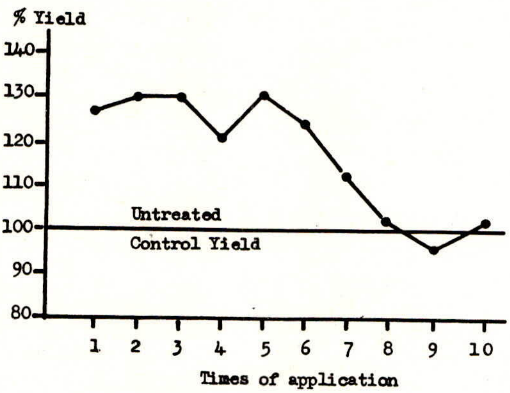

FIG. 2. BARLEY YIELD AS PER CENT OF CONTROLS

It is interesting to note that the barley yield was increased by approximately 20-30 per cent at seven of the ten application dates, in spite of the fact that 80 per cent wild oat control was only obtained at one of these dates.

DISCUSSION

Perhaps the most striking feature of the yield data obtained is the frequently considerable yield increase resulting from wild oat control with barban. The yield of cereal crops appears to be substantially increased even if only a part of the wild oat infestation was reduced. The authors realise that competition for water may have been particularly pronounced in the dry season of spring 1960.

The development stage of the cereal crop, with the exception of winter wheat in March, does not appear to be very critical as far as tolerance to barban is concerned.

Although on the basis of two years evidence 4 oz and 6 oz/ac of barban for wheat and barley respectively can be regarded as the optimum doses, no real objection can be seen for a standard dose of 5 oz/ac for both crops.

In general highest yields were obtained when spraying was carried out right at the beginning of the period when wild oats are sensitive (1-2½ leaf stage period).

APPENDIX

Experiment No. 1: Winter wheat var. Cappelle No wild oats

(Site:- Stumps cross) Control yield = 25.6 cwt/ac (8 reps/treatment)

Time of Application	Yield as per cent of control Treatments (oz of barban)			
	2	4	6	8
December 9th	99.7	106.1	102.7	97.7
January 25th	102.4	105.9	101.5	101.9
March 21st	100.9	95.7	85.9	77.3
April 4th	99.5	102.7	96.7	97.0
Statistical data (Split plot design) for P0.05	Sig. diff. for treatments at one time = 14.6 Sig. diff. for one treatment at different times = 9.2			

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used.

Experiment No. 2: Winter wheat var. Cappelle. No wild oats

(Site:- Pamplsford) Control yield = 38.4 cwt/ac (8 reps/treatment)

Time of Application	Yield as per cent of control Treatments (oz of barban)			
	2	4	6	8
December 21st	93.8	105.7	100.2	99.9
January 25th	95.7	103.7	95.4	88.0
March 21st	99.9	97.1	87.0	68.7
April 4th	96.1	98.6	93.3	89.9
Statistical data (split plot design) for P0.05	Sig. diff. for treatments at one time = 11.9 Sig. diff. for one treatment at different times = 7.4			

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used.

Experiment No. 3: Winter wheat var. Cappelle. No wild oats

(Site:- Swaffham) Control yield = 27.9 cwt/ac (8 reps/treatment)

Time of Application	Yield as per cent of control Treatments (oz of barban)			
	2	4	6	8
December 21st	98.0	97.8	99.8	97.4
February 2nd	95.2	100.0	89.7	78.6
March 22nd	96.2	79.1	66.8	56.4
April 4th	96.7	98.6	91.7	82.9
Statistical data (split plot design) for P0.05	Sig. diff. for treatments at one time = 11.8 Sig. diff. for one treatment at different times + 9.4			

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used,

Experiment No. 4: Winter barley var. Pioneer. No wild oats

(Site:- Wilbraham) Control yield = 17.4 cwt/ac (8 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz of barban)			
	2	4	6	8
December 2nd	107.1	97.6	88.7	92.6
December 21st	98.0	90.8	95.0	97.6
March 22nd	101.3	91.5	99.2	80.3
April 4th	110.1	95.4	101.4	106.4
Statistical data (split plot design) for P0.05	Sig. diff. for treatments at one time = 21.5 Sig. diff. for one treatment at different times = 16.6			

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used.

Experiment No. 5: Winter wheat var. Cappelle. Medium infestation of *Avena fatua*

(Site:- Eaton) Control yield = 36.7 cwt/ac (4 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz of barban)		
	2	4	8
November 17th December 17th	100.9 111.3	104.9 112.2	106.5 110.7
Statistical data	Sig. diff. (PO.05) = 18.4		

Experiment No. 6: Winter wheat var. Cappelle. Heavy infestation of *Avena fatua*

(Site:- Didcot) Control yield = 28.0 cwt/ac (4 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz of barban)		
	2	4	8
December 17th	122.7	114.8	131.2
Statistical data	Sig. diff. (PO.05) = 19.4		

Experiment No. 7: Winter wheat var. Cappelle. Medium Infestation of *Avena fatua*

(Site:- Kingston) Control yield = 35.4 cwt/ac (4 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz of barban)		
	2	4	8
December 16th	115.5	123.3	109.6
Statistical data	Sig. diff. (PO.05) = 23.9		

Experiment No. 8: Winter wheat var. Cappelle. Medium infestation of wild oats

(Site:- Chesterford) Control yield = 41.8 cwt/ac (6 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz barban)		
	2	4	8
March 22nd	108.3	108.8	97.1
April 6th	109.4	98.3	105.9
May 9th	100.9	100.5	99.9
Statistical data (split plot design) for P0.05	Sig. diff. for treatments at one time = 12.3 Sig. diff. for one treatment at different times = 13.0		

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used.

Experiment No. 9: Winter wheat var. Cappelle. Heavy infestation of wild oats

(Site:- Castle Camps) Control yield = 19.6 cwt/ac (6 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz of barban)		
	$2\frac{1}{2}$	4	8
March 10th	112.5	110.1	78.8
March 31st	122.2	127.7	105.7
May 9th	90.7	93.4	106.4
Statistical data (split plot design) for P0.05	Sig. diff. for treatments at one time = 31.2 Sig. diff. for one treatment at different times = 17.1		

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used.

(78178)

Experiment No. 10: Winter wheat var. Cappelle. Very heavy infestation of Avena ludoviciana

(Site:- East Hanney) Control yield = 18.3 cwt/ac (4 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz of barban)		
	2	4	8
January 12th	174.3	191.9	191.6
Statistical data	Sig. diff. (P0.05) = 59.9		

Experiment No. 11: Winter wheat var. Cappelle. Heavy infestation of Avena ludoviciana

(Site:- Chesterford Park) Control yield = 23.2 cwt/ac (3 reps/treatment)

Time of Application	Yields as per cent of controls Treatments (oz of barban)		
	2	4	8
February 5th	130.5	151.8	137.7
March 15th	143.8	148.7	105.2

This experiment was incomplete so no analysis was carried out.

Experiment No. 12: Winter wheat var. Cappelle. Heavy infestation of Blackgrass

(Site:- Chalgrove) Control yield = 17.7 cwt/ac (4 reps/treatment)

Time of Application	Yields as per cent of control Treatment (oz of barban)		
	2	4	8
November 20th	145.9	141.8	142.5
December 17th	108.1	132.1	143.3
Statistical data	Sig. diff. (P0.05) = 44.3		

Experiment No. 13: Spring wheat var. Koga 11. Very heavy infestation of wild oats

(Site:- Whittlesford) Control yield = 16.0 cwt/ac (12 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz of barban)		
	2½	4	8
April 8th April 15th April 22nd	105.4 103.2 89.6	112.8 103.2 117.2	106.2 79.4 103.2
Statistical data (split plot design) for P0.05	Sig. diff. for treatments at one time = 14.2 Sig. diff. for one treatment at different times = 10.9		

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used.

Experiment No. 14: Spring wheat var. Jufy 1. Medium infestation of wild oats

(Site:- Hadstock) Control yield = 32.2 cwt/ac (12 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz of barban)		
	2½	4	8
April 11th April 20th April 27th	109.6 109.1 109.9	113.9 112.9 110.1	107.3 104.9 104.4
Statistical data (split plot design) for P0.05	Sig. diff. for treatments at one time = 5.1 Sig. diff. for one treatment at different times = 4.7		

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used.

Experiment No. 15: Spring wheat var. Atle. Medium infestation of wild oats

(Site:- Haverhill) Control yield = 18.6 cwt/ac (12 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz of barban)		
	2½	4	8
April 27th	102.7	108.8	108.6
May 4th	99.7	100.0	105.9
May 11th	89.8	89.0	94.8
Statistical data (split plot design) for P0.05	Sig. diff. for treatments at one time = 10.5 Sig. diff. for one treatment at different times = 9.3		

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used.

Experiment No. 16: Spring wheat var. Koga 11. Very light infestation of wild oats

(Site:- Castle Camps 1) Control yield = 18.5 cwt/ac (12 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz of barban)		
	2½	4	8
April 20th	101.8	103.4	92.4
April 27th	98.0	102.1	87.6
May 4th	97.7	98.1	103.7
Statistical data (split plot design) for P0.05	Sig. diff. for treatments at one time = 5.7 Sig. diff. for one treatment at different times = 5.3		

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used.

Experiment No. 17: Spring wheat var. Jufy 1. No wild oats

(Site:- Castle Camps 11) Control yield = 36.4 cwt/ac (12 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz of barban)		
	2½	4	8
April 16th April 25th May 2nd	98.1 98.6 95.6	97.8 96.3 97.4	90.8 85.9 87.7
Statistical data (split plot design) for P0.05	Sig. diff. for treatments at one time = 4.9 Sig. diff. for one treatment at different times = 4.6		

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used.

Experiment No. 18: Spring barley var. Rika. Heavy Infestation of wild oats

(Site:- Boxworth) Control yield = 20.1 cwt/ac. (7 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz of barban)		
	4	6	8
May 5th May 16th May 23rd	101.0 102.5 102.4	111.9 99.7 103.5	115.4 99.5 100.5
Statistical data (split plot design) for P0.05	Sig. diff. for treatments at one time = 18.6 Sig. diff. for one treatment at different times = 14.7		

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used.

Experiment No. 19: Spring barley var. Rika. Heavy infestation of wild oats

(Site:- Chesterford Park) Control yield = 18.7 cwt/ac (12 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz of barban)		
	4	6	8
April 15th April 22nd April 29th	106.3 106.0 103.5	124.6 105.9 110.6	113.6 91.7 105.3
Statistical data (split plot design) for P0.05	Sig. diff. for treatments at one time = 13.3 Sig. diff. for one treatment at different times = 10.6		

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used.

Experiment No. 20: Spring barley var. Herta. Heavy infestation of wild oats

(Site:- Castle Camps) Control yield = 34.5 cwt/ac (12 reps/treatment)

Time of Application	Yields as per cent of control Treatments (oz of barban)		
	4	6	8
April 21st April 29th May 9th	114.6 110.2 98.6	111.5 110.1 104.0	111.2 113.9 107.5
Statistical data (split plot design) for P0.05	Sig. diff. for treatments at one time = 8.0 Sig. diff. for one treatment at different times = 7.5		

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used.

Experiment No. 21: Spring barley var. Rika. Heavy infestation of wild oats

(Site:- Chesterford) Control yield = 25.5 cwt/ac (12 reps/treatment)

Time of Application	Yields as per cent of controls Treatments (oz of barban)		
	4	6	8
April 15th April 22nd April 29th	118.7 119.1 110.4	119.8 115.6 111.1	121.8 107.7 112.5
Statistical data (split plot design) for P0.05	Sig. diff. for treatments at one time = 10.2 Sig. diff. for one treatment at different times = 8.1		

For comparison with control (100 per cent) the sig. diff. for one treatment at different times should be used.

FIELD RESULTS ON THE RELIABILITY OF BARBAN FOR THE CONTROL OF WILD OATS IN CEREALS

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Summary: Performance and reliability of barban was assessed in 84 field trials in the 1960 crop season. Field trials consisted of development trials, ground and aircraft application, and farmer trials. Both the development and farmer trials illustrate that if wild oats are sprayed with barban when 70-80 per cent are in the 1½-2½ leaf stage good control is achieved. Of the farmers who reported they were not satisfied with the results of their trials 72 per cent had sprayed either at an incorrect wild oat stage or at an incorrect dose. The farmer trials revealed that wild oat control below 70 per cent is unacceptable to the farmer. The general performance of barban in the 1960 trials is in line with the results obtained in the 1959 trials, even though the weather conditions experienced in each season were quite different.

INTRODUCTION

Following encouraging results of experiments with barban in 1959 it was decided to test the reliability of barban applied under very varied field conditions in 1960. With the knowledge that the stage of growth of wild oats was very critical for good control the work aimed at comparing the reliability of barban's performance under well controlled development field trials and under normal farming conditions.

The doses used were 6oz barban/ac for spring barley and 4oz barban/ac for spring and winter wheat, which were the ones tentatively recommended as a result of trials carried out in 1959. An additional aim of the 1960 work was to test the reliability of these rates.

I DEVELOPMENT TRIALS

The development trials comprised (a) Eighteen sites ranging from South of Oxford, through Northamtpon, Essex, Suffolk, Norfolk, to North Lincolnshire. Each of these sites was sprayed by ground machine with accurate doses of barban at a known and recorded correct stage of wild oat growth, that is when 70-80 per cent of the wild oats were in the 1½-2½ leaf stage.

(b) Five sites in the vicinity of Cambridge, and one in Essex sprayed by aircraft at varied stages of wild oat growth.

MATERIALS AND METHODS

Chemical: An emulsifiable concentrate containing 11.8% w/v barban.*

* As "Carbyne"

Ground Application The Chesterford Logarithmic Sprayer was used to apply at each site (a) One logarithmic strip starting at 12oz barban/ac peak. (b) Constant doses of 4, 6 and 8oz barban/ac, each applied in strips 5 yd wide by 60 yd long. All the above treatments were applied in 18 gal of water/ac.

Aircraft Application: A helicopter was used to apply 4oz barban to spring wheat and 6oz barban to spring barley in 3 gal of water/ac. Aircraft application was made to 5 ac plots and was compared with the same dose applied by ground machine to a 5 x 60 yard strip in 18 gal of water/ac. A control strip was left at each site for comparison.

RESULTS

The results of the development trials are given in Tables I and II. Two assessments were made of all these sites during the season. At both, assessments of wild oat panicles above and below the crop were made. On some sites during the last assessment, counts of wild oat panicles were made and these are underlined in Table I. Although it was intended to make wild oat counts on all the sites during the last assessment, it was mostly found impossible owing to the effect of severe storms in July. Wild oat panicles below the level of the crop were greatly reduced in size and their presence varied from site to site. The number mainly depended on the number of wild oats germinating after spraying or which were past the 2½ leaf stage at spraying time. Stunted wild oats were always less or absent in the higher-dose plots.

TABLE I. PER CENT WILD OAT CONTROL ACHIEVED IN DEVELOPMENT TRIALS

GROUND MACHINE APPLICATIONS

SPRING BARLEY

Expt No.	County	Variety	W.O. density /sq yd	4oz	per cent control 6oz	8oz	12oz (log strip)
1	Oxford	Vada		85-90	95	98	98
2	Norfolk	Herta	20	88	95	99	99
3	Suffolk	Rika		75-80	95	98	98
4	Lincs	Rika		75-80	80	85-90	95
5	Lincs	Rika	13	76	74	89	93
6	Hunts	Rika		75	85-90	95	98
7	Lincs	Rika		75	85-90	95	98
8	Lincs	Rika	11	62	80	91	98
9	Lincs	Rika		60	85-90	98	98
10	Lincs	Rika	6	60	90-95	95	98
		range (as percentage)		60-90	74-95	85-98	93-99
		mean (as percentage)		73.2	87.2	94.5	97.3

Percentages underlined are based on actual wild oat counts

SPRING WHEAT

TABLE I (Contd.)

Expt No.	County	Variety	W.O. density /sq yd	4oz	per cent control 6oz	8oz	12oz (log strip)
1	Lincs	Koga II		85-90	95	98	98
2	Lincs	Koga II		85-90	90	95	98
3	Suffolk	Koga II	11	92	95	99	99
4	Norfolk	Koga II		75-80	90-95	98	98*
5	Lincs	Jufy I	17	85	99	99	99
6	Lincs	Koga II		75	95	98	98
		range (as percentage)		75-92	90-95	95-99	98-99
		mean (as percentage)		83.8	95	97.8	98.5

WINTER WHEAT

Expt No.	County	Variety	W.O. density /sq yd	4oz	per cent control 6oz	8oz	12oz (log strip)
1	Lincs	Cappelle		90	95	95-98	98
2	Lincs	Mills Wonder		70	75-80	90	95

* Wild oat infestation sparse in all treatment plots

TABLE II PER CENT WILD OAT CONTROL ACHIEVED IN DEVELOPMENT TRIALS

AIRCRAFT APPLICATIONS

SPRING BARLEY - 6oz barban/ac

Site	Variety	Aircraft - 3 gal/ac per cent W.O. control	Land Machine - 18 gal/ac per cent W.O. control
1	Rika	80-85	90-95
2	Rika	Poor	Poor
		60-70 per cent wild oats beyond 2½ leaf stage	
3	Rika	Poor	Poor
		30-35 per cent wild oats beyond 2½ leaf stage	
4	Carlsberg	Poor	Poor
		30-35 per cent wild oats beyond 2½ leaf stage	

No effect on crop except from aircraft application at site 6 where slight depression recorded at first but not visible later.

* Percentages underlined are based on actual wild oat counts.

The 60 farmer trials have been divided into 10 groups ranging from no wild oat control to 100 per cent wild oat control, and the number of trials in each group is shown in two histograms (Figures 3 and 4). In Figure 3 all 60 trials are plotted, including all the failures due to faulty application. Figure 4 excludes all the failures due to faulty application, that is, mostly late spraying when the wild oats are past the $1\frac{1}{2}$-$2\frac{1}{2}$ leaf stage.

Comparing the results expressed in Figures 2-4 it can be seen that:-

1. The mean percentage wild oat control obtained in:-

   (a) the development trials (excluding aircraft application) is 86 per cent

   (b) all farmer trials is 60 per cent

   (c) farmer trials excluding inaccurate application is 79 per cent.

2. The percentage probability of wild oat control is as follows:-

   (a) carefully controlled development trials - probability of 71-80 per cent wild oat control = 95 per cent

   (b) all farmer trials - probability of 71-80 per cent wild oat control = 55 per cent

   (c) farmer trials excluding incorrect application - probability of 71-80 per cent wild oat control = 77 per cent

This very clearly illustrates the increasing reliability of wild oat control with barban, with increasingly accurate timing of the spray application.

EFFECT OF BARBAN ON THE CROP

Only one case of crop damage was reported in the farmer trials and this was on Atle spring wheat. There was no visible effect in any barley crop at doses up to 12oz barban/ac. At doses up to 8oz in wheat two cases of crop damage were observed in spring wheat, variety Koga II, and winter wheat, variety Mills Wonder. Damage appeared as slightly retarded growth which generally looked more severe in the early stages of crop growth. Later in the season only a very slight check, if any, was visible in the crop.

DISCUSSION

The work clearly indicates that accurate timing of a barban spray is probably the most important factor contributing to successful wild oat control. As weed control becomes increasingly more specialised and application time and techniques more critical, it is obvious that farmers will at first find some difficulty in using new chemicals efficiently. This is particularly the case where barban is concerned, since not only is it difficult for a farmer to time his spray when the wild oats are in the correct stage, but it is in many cases difficult for him to identify the wild oats present amongst his crop.

Figure 2

BARBAN DEVELOPMENT TRIAL RESULTS (18 SITES)

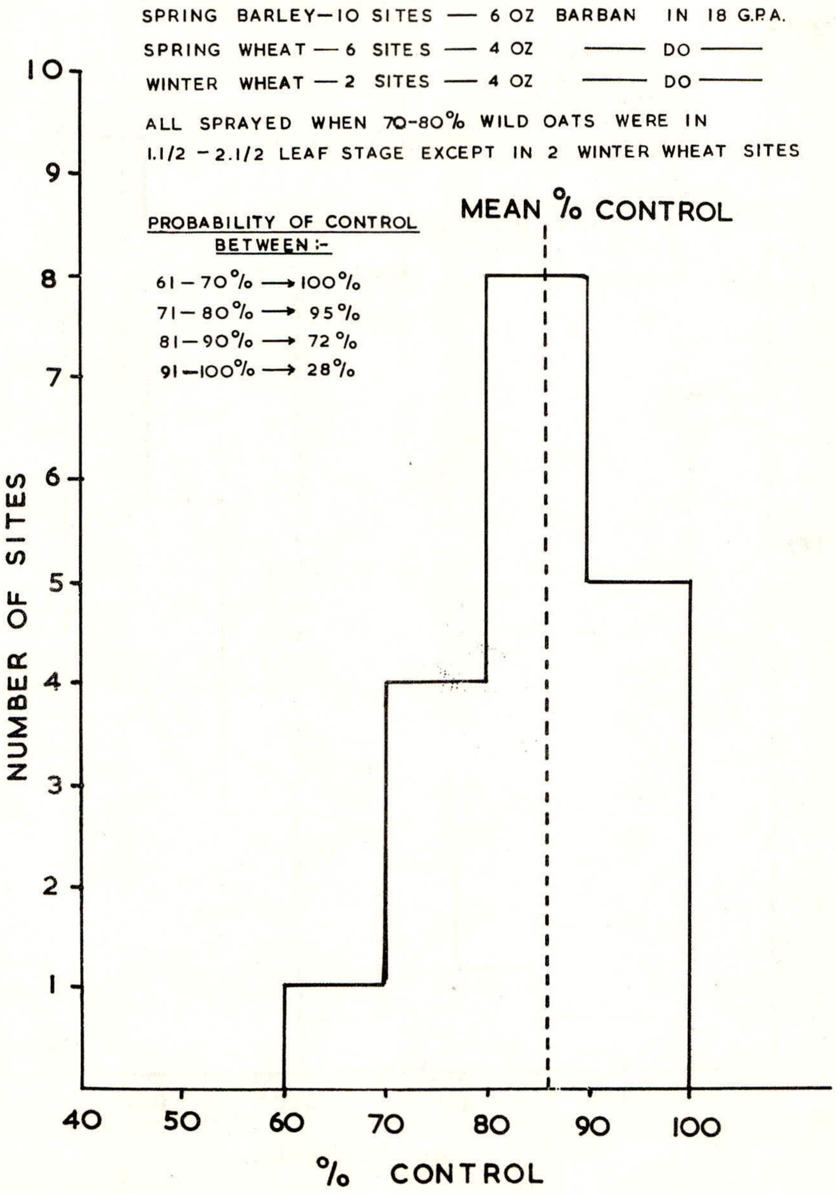


Figure 3

BARBAN FARMER TRIAL RESULTS 60 SITES

Farmers Opinion

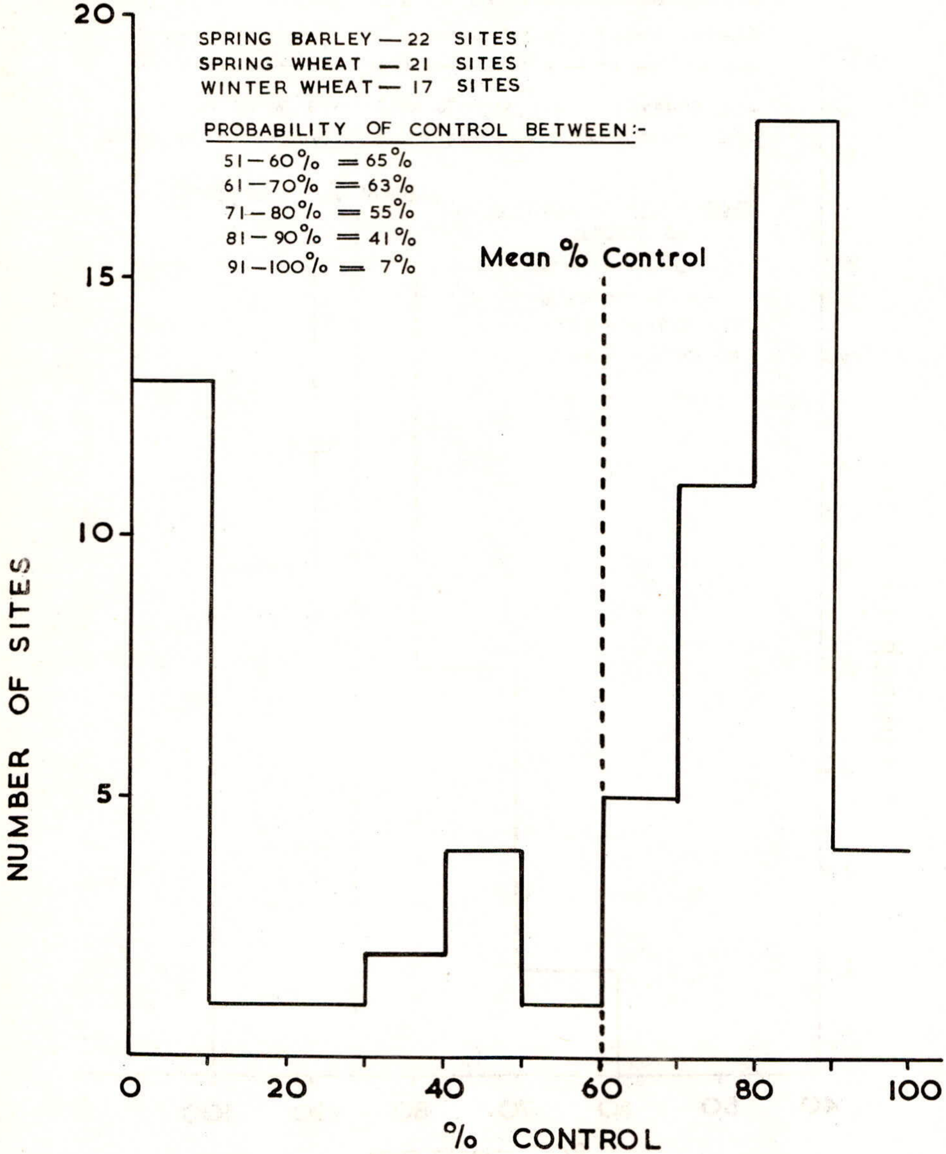
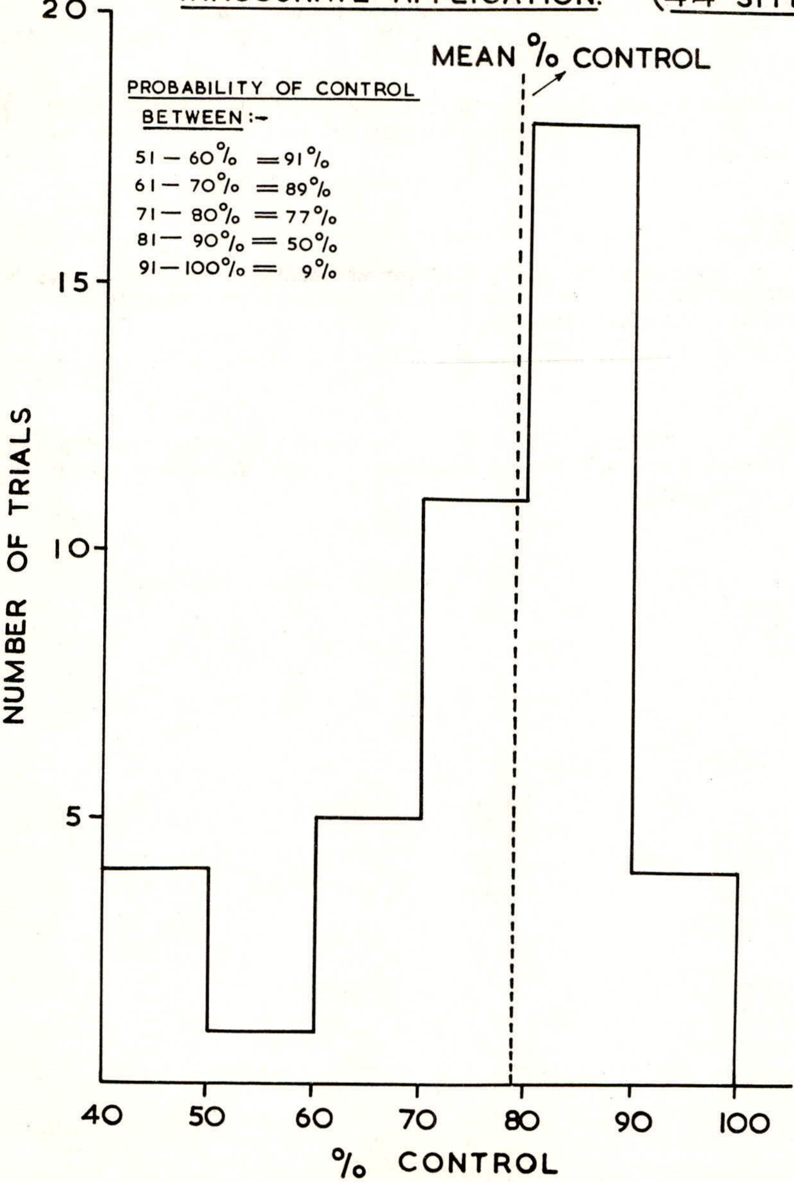


Figure 4

BARBAN FARMER TRIAL RESULTS, OMITTING INACCURATE APPLICATION. (44 SITES)



(78178)

It should also be borne in mind at for the 1960 farmer trials only a limited amount of simple advice could be provided. In future years more comprehensive advice will be given to the farmer, which will aid him to identify wild oats amongst grasses and cereals and to time his spray correctly.

Considering these points, the results of farmer trials in the 1960 season can be considered encouraging and with increasing experience following education on wild oats it can be expected that farmers will, in the future, be able to achieve results comparable with those obtained in the development trials reported above.

It is interesting to note that the results reported in this paper are in line with the results obtained from trials carried out in 1959 under very different weather conditions.

Acknowledgements

The writer is indebted to Dr. R. K. Pfeiffer who designed the experiments and suggested the method of assessing the results which are presented in the manner used by Holmes and Pfeiffer (1956.)

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THE PERFORMANCE OF 2,3-DICHLOROALLYL DIISOPROPYLTHIOLCARBAMATE IN THE WILD OAT AREAS OF NORTH AMERICA

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INTRODUCTION

In the vast prairie provinces of Canada and the northern tier of the United States from the Great Lakes to the Pacific ocean, the wild oat (Avena fatua) ranks as the number one weed problem. This weed has invaded some 61 million acres of crop - of which half is considered as seriously infested. Recommended cultural practices (McDonald, B.K. 1949) which include repeated tillage during early spring, and delayed seeding of the crop, are partially successful in controlling this widespread pest. However, delayed seeding often resulted in substantial crop reduction, which, added to the expense of tillage, made such a programme quite costly. Furthermore, in a cold wet spring, delayed seeding was not always effective.

Early in the 1950's attention was turned to the evaluation of chemicals as a possible aid to the farmer in his battle against the wild oat. Two of the first chemicals to meet partial success were isopropyl N-phenylcarbamate (IPC) and iso-propyl N-(3-chlorophenylcarbamate (CIPC) (Anon. 1956). However, their use has been limited to such minor crops as peas and sunflower. With the inconsistent performance of the chemical and its high cost of $10 to $12 per acre, there has been limited farmer acceptance. During the last five years it has been estimated that over 75 chemicals have been field tested as a possible wild oat herbicide. Early in this period 2-chloro-NN-diallylacetamide (CDAA) was evaluated by several experiment stations and found, under certain conditions, to give good control (Friesen, G. 1956). In subsequent testing, results varied from excellent to poor and it was dropped from further consideration because good wild oat control was obtained in less than 50 per cent of the trials (Leggett, H. W. 1957). At about the same time another chemical, 1,2,4,5-tetrachlorobenzene, was widely tested but it too failed to give acceptable wild oat control. (Leggett, H. W. 1957).

The Monsanto Chemical Company's Agricultural Research Laboratory conducted exhaustive studies, screening thousands of potential wild oat chemicals. From this programme, several chemicals were submitted to selected research personnel for field testing as a pre-planting treatment. Results from these early trials indicated that one chemical (2,3-dichloroallyl diisopropylthiolcarbamate) consistently controlled wild oats in a wide variety of agronomic crops (Selleck, G. W. 1958).*

METHODS AND MATERIALS

This new chemical was so outstanding that it was decided to demonstrate it under conditions on several commercial farms in Canada and the United States. In co-operation with weed research personnel and Monsanto's distributors of Agricultural Pesticides, farmer-co-operators were selected for an on-the-farm demonstration programme. The widely scattered fields selected for these trials were known to be heavily infested with wild oats. At most of the locations, doses of 1, 1.25, 1.5, 1.75 and 2 lb/ac were applied using the farmer-co-operator's sprayer. The volume of water used in making the applications

*Monsanto has adopted the trademark "Avadex" for the product developed from this compound.

area of the United States, at 1.5 lb/ac, an increase of 965 lb/ac was obtained over the untreated plot. In wheat where the stand was reduced 25 per cent by 1½ lb, the treated plot yielded 19 bush compared to 10 bush in the untreated plot.

Residue studies have been conducted to comply with the requirements of the Food and Drug Administration in the United States and Canada. Analysis shows that the chemical does not exist in the mature plants that have been harvested from plots treated with doses as high as 6 lb/ac. These crops are barley, peas, flax, sugar beets, wheat, sunflower, rapeseed and lentils. The chemical is presently registered in Canada for sales on a "no residue" basis and it is anticipated this will also be the case in the United States.

DISCUSSION

Based on the results of several years work by Experimental Stations, of field testing and one year of commercialization, the following conclusions regarding 2,3-dichloroallyl diisopropylthiolcarbamate may be made.

At a dose of 1½ lb/ac it has given consistent 90 to 99 per cent wild oat control both under controlled experimentation and farmer use. Flax, barley, sugar beets, lentils, peas, sunflower, safflower, rapeseed, potatoes, alfalfa, clovers, Kentucky bluegrass and orchard grass, demonstrated tolerance to doses required for satisfactory wild oat control.

Preliminary field and greenhouse data indicated that wheat at doses ranging from 1 to 1½ lb/ac is tolerant when seeded to treated areas where chemical is not incorporated to depths greater than 2 in. Data which are available from the majority of the farmer tests show a substantial increase in crop yields from the use of this herbicide. The heavier the infestation, the greater the increase in yield. Wild oat control is increased only slightly when doses higher than 1½ lb/ac are used provided proper incorporation procedures are followed at the lower doses. Soil should be in good working condition at the time of applying the chemical to ensure proper mixing.

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THE USE OF BARBAN FOR THE CONTROL OF AVENA FATUA

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Summary: During 1960 a series of experiments was carried out to investigate the effect of barban on the yields of clean crops of spring wheat and barley (a resistant variety), and wild oat (A. fatua) in crops of spring wheat and spring barley.

The yield trials showed that if the crop had 3 leaves at the time of application even 12 oz of barban had little effect on the yield. There was, however, a tendency, particularly with spring wheat, for susceptibility to increase with age. In contrast, wild oat was susceptible at an early stage of growth (1-2½ leaf stage) and their resistance increased with age.

MCPA-triethanolamine applied at 1½ lb ae/ac when the crop had 5 leaves, did not interfere with the effect of barban applied about a week earlier. However, if MCPA was applied at the same time as the barban the control of wild oat was reduced, although the susceptibility of the crop was increased. The need to assess the total number of spikelets produced, rather than merely the number of panicles above the crop is also emphasised.

INTRODUCTION

Barban (4-chloro-2-butynyl N-(3-chlorophenyl) carbamate) has been developed as a post-emergence chemical for the control of wild oat in cereals (Corns, 1958; Hoffman et al. 1958). During 1959 it was tested on a fairly large scale in this country by Fisons Pest Control Ltd., and preliminary trials were also carried out by the A.R.C. Unit of Experimental Agronomy. These trials confirmed the earlier reports from the United States of America (Brown, 1958; Hoffman et al., 1958), that wild oat is most susceptible when it has from 1 to 2½ leaves. Plants treated with an appropriate dose of barban cease to grow and form a characteristic rosette of short, broad, bluish-green leaves; the stem apices fail to develop primordia and it is thought that, like most carbamates, it acts as a mitotic poison.

Although, even in the absence of crop competition, barban kills wild oat at doses that are not harmful to certain cereals, vigorous crop competition has been shown to be necessary if full advantage is to be taken of the check to the survivors. Regrowth is then limited. The volume of spray applied per acre is also important for the formulation used and it is generally agreed that increasing the rate from 10 to 100 gal/ac reduces the effectiveness of this herbicide by almost half. (Holly, 1960; Holroyd, 1959).

Many spring wheats and spring barleys are fairly resistant to barban, but the barley varieties Provost and Proctor are exceptions (Pfeiffer et al. 1960; Holroyd, 1959).

Mixtures of barban with other herbicides showed a marked antagonism with 2,3,6-TBA and to a lesser degree with other auxin herbicides (Pfeiffer et al. 1960; Holroyd, 1959).

In 1960 therefore a number of experiments were laid down to investigate the effect of barban on the yields of clean crops of spring wheat and barley, the interaction of barban with a standard dose (1½ lb/ac) of MCPA, and the effect of barban on *Avena fatua* at different stages of growth when growing in crops of spring wheat and barley.

METHODS AND MATERIALS

Yield Trials. Four yield trials were laid down on clean cereal crops in 1960, two on spring wheat and two on spring barley. The same design and treatments were used in each trial. The spraying was carried out with a Land Rover mounted sprayer, using plots of 40 yd x 5 yd. The barban was formulated in an emulsifiable oil* and applied in water at a volume rate of 13.4 gal/ac.

The treatments were 4, 8 and 12 oz/ac of barban applied when the crop had a) approximately 3 leaves - date I, and b) approximately 5 leaves - date II. The experimental design was a randomised block replicated four times with one control plot in each block. The control plots in the odd numbered blocks were wheel marked at date I and those in the even numbered blocks at date II. At harvest yields of grain were obtained by harvesting a strip down the centre of each plot with a combine harvester.

Trials on *Avena fatua* in spring cereals. Four experiments were laid down in 1960. The same formulation of barban was used as in the yield experiments. The treatments were applied with an Oxford Precision Sprayer to plots which were 6 yd x 2 yd. The volume rate was 15 gal/ac.

The experimental design was a randomised block replicated three times. A discard strip of 1 yd was left between plots.

Experiment at Harwell, Berks.

This experiment was on a crop of Carlsberg spring barley grown under conditions of moderate fertility, with a moderate infestation of *A. fatua* (17 panicles/sq yd). The germination of the crop was uneven due to the dry spring; it evened up later in the season but its competitive ability was never high.

Experiment at Bretford, Nr. Evesham.

The crop was Carlsberg, spring barley growing under conditions of high fertility. The treatments were 0, 4, 8 and 12 oz of barban applied at three times. This crop was unfortunately badly laid early in July, so that although its competition with the oats was very vigorous in the early stages, many of the panicles, particularly the smaller ones, had little or no competition for light in the later stages of development.

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* 'Carbyne' containing 11.8 per cent w/v barban, Fisons Pest Control.

Experiment at Shillingford, Oxon.

The crop here was spring wheat, var. Atson, growing under conditions of high fertility. The A. fatua plants were very variable and the growth stages ranged from 1 leaf to fully tillered. Adjacent controls were used for each treated plot.

Experiment at Broadchalke, Nr. Salisbury, Wilts.

This was on spring wheat var. Atle, growing under conditions of moderate fertility.

Assessment. The stage of growth of A. fatua at the time of spraying was assessed by selecting 20 plants at random on each of the sprayed plots. Visual observations were made at intervals and during the latter part of July all the A. fatua panicles were counted on the plots and classified according to:

their position above or below the crop,
their size (a) small 1-10 spikelets
(b) medium 10-30 spikelets
(c) large 30 or more spikelets
their stage of growth
(a) fully expanded
(b) just emerging from the sheath
(c) still within the sheath.

The stage of growth of the crop was assessed by selecting six samples of ten plants at random over the experimental area.

RESULTS

Yield trials. The results are shown in Table I. These show that Rika barley and the spring wheats Koga II and Jufy are unaffected by up to 12 oz/ac of barban applied at the 3 leaf stage. In fact little or no damage was visible on the crops at any time subsequent to spraying. If, however, applications were delayed until the 5 leaf stage Koga II in particular was checked in growth and the 12 oz/ac treatment reduced the crop height and the head size. This resulted in a 30 per cent fall in the yield. The 4 oz and 8 oz treatments also produced effects but these were less marked. The crops of Jufy and Rika were little affected. There was a significant difference between the mean yields of Rika at the two times, T_1 and T_2 in the Towcester experiment which was most probably due to 'wheel-marking' a high yielding crop later in development, as there was no dose trend and no interaction between dose and time of application.

Trials on A. fatua in Spring Cereals. The results of these are shown in Tables II, III, IV and V. Two sets of figures are given, one referring to the number of spikelets visible above ('above') the crop and the other to the total ('total') number of spikelets. The figures are based on the counts, but have been weighted for size of panicles. It has been assumed for the purpose of calculation that the small panicles had a mean of 5 spikelets, the medium 20 and the large 40. Although a spikelet may contain from 1-3 viable seeds these figures do give a more accurate estimate of the number of actual seeds produced than panicle counts alone. In tables II, III, IV and V control counts at the different treatment times (T) have been averaged. The control counts for

Table IV were made on the discards between each pair of treated plots, a total of nine, and averaged.

The results of the trials in which treatments were applied at different times (T) are fairly consistent and show conclusively that A. fatua was most sensitive at the 1-3 leaf stage. At this stage 8 oz barban/ac reduced the total spikelets by over 70 per cent and 4 oz by 40-66 per cent. The apparent control, i.e. the reduction in numbers of wild oat panicles above the crop was even better, 76-85 per cent for 4 oz/ac treatment. As the numbers of wild oat at the susceptible stage decreased so the effectiveness of the barban declined, and 9-11 days later when the number of A. fatua at the 1-3 leaf stage had dropped by 51-56 per cent, 8 oz barban gave a reduction which varied from 13-42 per cent, although the apparent control was approximately 70 per cent. When treatment was delayed further until 84 per cent of the wild oat was at the 3-5 leaf stage, as at Harwell, the reduction became almost negligible.

The spring wheat at Shillingford was a very competitive crop but also sensitive, presumably as the spraying was late. Thus the 4 oz treatment gave the best control. Increasing the dose reduced the competitive powers of the crop and allowed the wild oat to recover. Also as the crop was growing strongly at the time of treatment, many of the oats, particularly those germinating late, were shielded and thus probably received little or no spray.

MCPA applied after barban (the shortest time interval was 9 days) had little effect on the degree of control, in fact at Broadchalke the MCPA itself seemed to give some reduction. However, when the barban and the MCPA were applied together at the second date (T2) there was a very marked interaction as measured by the toxicity of the chemicals to wild oats. At both Harwell and Broadchalke the effectiveness of the 12 oz treatment of barban was more than halved, although this antagonism was less marked at the lower doses. The position is complicated as the mixture was damaging to the crop and the damage increased as the proportion of barban was increased. The wheats suffered more than the barley although there was also very marked scorch on the barley at Harwell shortly after treatment. However, here the crop recovered almost completely. The damage on the wheat was characterised by a reduction in height, head length, and number of heads. Symptoms similar to those observed on Koga II in the yield experiment at Porton. This damage was accompanied by a number of head deformities such as 'opposites' and sterile ears, which did not occur in the absence of MCPA.

DISCUSSION

These results show that (a) the varieties of cereals tested were resistant at the 3 leaf stage and some of the spring wheat varieties tended to become more susceptible with age, (b) there was no interaction between barban and MCPA applied later, and (c) A. fatua was most susceptible at the 1-3 leaf stage.

Thus it follows that the maximum control of A. fatua will be obtained from barban treatments which are applied when the main flush has 1-3 leaves. At this time the crop will generally have approximately 3 leaves. MCPA can then be applied as usual when the crop has 5 leaves.

When A. fatua plants which had just begun to tiller were treated with barban, growth was checked and the existing tillers were stunted and often eventually died.

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164

TABLE I. YIELDS OF SPRING CEREALS TREATED WITH BARBAN, IN CWT/AC CORRECTED TO 15 PER CENT MOISTUREE

Experiment at	Crop	Date of Spraying	Stage of Growth	Treatment in oz/ac of barban				Mean	Coef. of variation	L.S.D. (P = 0.05) Treatment means	T_1 v. T_2
				0	4	8	12				
Porton, Wilts	S. Wheat	4.5.60. (T_1)	3-4 leaves	30.2	30.9	32.6	32.4	31.7			
	Koga II	12.5.60. (T_2)	5 leaves	31.0	31.2	29.9	20.7	28.5	16.2%	9.6	N/S
Porton, Wilts	S.Barley	4.5.60. (T_1)	3-4 leaves	18.45	18.9	18.1	18.4	18.5			
	Rika	12.5.60. (T_2)	5 leaves	18.4	17.1	18.0	18.2	17.4	8.9%	N/S	N/S
Bedford.	S.Wheat	29.4.60. (T_1)	3 leaves	27.0	26.4	26.8	26.6	26.7			
	Jufy	10.5.60. (T_2)	5-5½ leaves	27.1	26.1	25.9	26.4	26.3	3.7%	N/S	N/S
Towcester.	S.Barley	9.5.60. (T_1)	3-3½ leaves	43.0	41.7	41.4	42.7	42.1*			
	Rika	23.5.60. (T_2)	5-6 leaves	39.1	39.6	40.8	37.8	39.4	4.2%	3.3	1.3

(N.B. * There was no interaction between dose and time).

TABLE II. THE EFFECT OF BARBAN AND BARBAN/MCPA MIXTURES ON A. FATUA AT HARWELL, BERKS.

Number of spikelets expressed as a percentage reduction of controls (mean of 3 replicates)

Date of spraying:		14.5.60. (T_1)		25.5.60. (T_2)		1.6.60. (T_3)	
Stage of growth) Barley No. of leaves:) A. fatua		3-3½ 1-3 (86 per cent)		5-5½ 3-5 (65 per cent)		5-6 3-5 (84 per cent)	
Treatment:		'above' (1)	'total' (2)	'above' (1)	'total' (2)	'above' (1)	'total' (2)
4 oz barban/ac)	without MCPA	87	66	61	39	-27*	-23*
8 oz barban/ac)		94	85	70	42	4	8
12 oz barban/ac)		95	90	83	64	1	- 9*
0 oz barban/ac)	with MCPA at	13	5	3	5		
4 oz barban/ac)	1½ lb/ac	82	64	56	44		
8 oz barban/ac)	applied on	91	83	56	29		
12 oz barban/ac)	25.5.60.	95	88	63	28		
Control plots: (average of 3 dates)	407 spikelets/sq yd 'above' the crop. 550 spikelets/sq yd 'total' count.						

TABLE III. THE EFFECT OF BARBAN AND BARBAN/MCPA MIXTURES ON A. FATUA AT BROADCHALKE, WILTS.

Number of spikelets expressed as a percentage reduction of controls (mean of 3 replicates)

Date of spraying:		3.5.60. (T_1)		12.5.60. (T_2)	
Stage of growth) Wheat No. of leaves:) A. fatua		3-3½ 1-3 (81 per cent)		5 3-5 (71 per cent)	
Treatment:		'above' (1)	'total' (2)	'above' (1)	'total' (2)
4 oz barban/ac)	without MCPA	76	40	25	-24*
8 oz barban/ac)		93	73	78	13
12 oz barban/ac)		93	78	91	67
0 oz barban/ac)	with MCPA	37	17	37	37
4 oz barban/ac)	at 1½ lb/ac	82	53	39	25
8 oz barban/ac)	applied	90	78	61	22
12 oz barban/ac)	on 12.5.60.	90	83	75	24
Control plots: (average of two dates)	112 spikelets/sq yd 'above' the crop. 225 spikelets/sq yd 'total' count.				

* The negative sign indicates that there was an increase over control.

(1) These figures show the number of spikelets 'above' the crop expressed as a percentage reduction from the number above the crop on the controls.

(2) These figures refer to the total number of spikelets.