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THE INFLUENCE OF MINIMUM CULTIVATIONS ON THE GROWTH OF CULTIVATED PLANT ROOTS

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Summary In experiments in which mechanical cultivation was replaced by paraquat, the growth dynamics of the root systems of wheat, oats and yellow lupin was studied, using the isotope ^{32}P.

In 1966, a wet year, comparing crops grown after normal cultivations, and after paraquat with no cultivations, the growth dynamics of the root and stem systems of oats and wheat were similar, and grain yields were not affected.

However, the growth of lupin roots and stems were reduced by the paraquat no-cultivation regime, resulting in lower yields of seed and straw.

In 1967, a dry year, only oats were unaffected by the two cultivation systems in terms of growth dynamics and yield.

Wheat and lupins grew more slowly and yields were lower when these crops were grown without cultivations.

INTRODUCTION

The use of paraquat instead of cultivations for the control of weeds before seeding can by changing water relations and soil compaction, exert some influence on the growth dynamics of the root systems of young plants. Jeater (1965,1966) proved, with different crops, thatvdirect drilling on good textured soils with satisfactory water reserves had no adverse effect on yields. However, there is a lack of information concerning the possibility of "chemical cultivations" on soils with poorer textures.

The sandy soils of Lower Silesia are characterised by a compacted laminar structure, low water tables (mostly at a depth of 2 - 5 m) and high permeability because of low humus, silt, clay and colloid fractions. Another feature is the rapid lowering of the water table in spring and during times of drought. These factors can prevent emerging spring crops from developing deep root systems early enough to reach the moisture and so avoid low yields. In addition, the penetration of roots into these soils may be impeded by the compact laminar structure which remains undisturbed under the simplified - so called "chemical" - cultivation system which might then prove unsuitable. Therefore the only way to solve this problem was to make an examination of the growth dynamics of the root systems of crops grown in these sandy soils.

METHODS AND MATERIALS

Experiments were carried out in 1966-1967 at the Institute of Cultivation, Fertilisation, and Soil Science, Laskowice Oławskie near Wrocław on light sandy soils of fluvioglacial origin. The crops examined were spring wheat, (winter wheat in 1967), oats and yellow lupins, all following winter rye which was the last crop in a five course rotation of potatoes, oats, lupins, winter wheat and rye.

The cultivation treatments were :-

1. Normal cultivations

2. Direct drilling with weed control by paraquat at 3 l/ha

The root development of the test crops during the growing season was measured by the method developed by Swietochowski and Glabiszewski (1959, 1962) using ^{32}P under field conditions.

RESULTS

The rainfall during the period May - July differed widely in the two years concerned. 1966 was a wet growing season while 1967 can be considered rather dry.

Table 1

Monthly rainfall (mm) May - July

	1966	1967
May	67.6	64.2
June	74.1	57.8
July	122.2	33.8
Total	263.9	155.8

The rainfall distribution was uneven in both years. In 1966 the greatest amount fell in July, too late for the crops, whilst in May the only rainfall of note occurred towards the end of the month. In 1967 the month of May was humid with rainfall evenly distributed. In both years the June rainfall was fairly even distributed.

Figures 1 and 2 show the measurements of the test crops for 1966 and 1967 together with the rainfall distribution for the growing period in each year.

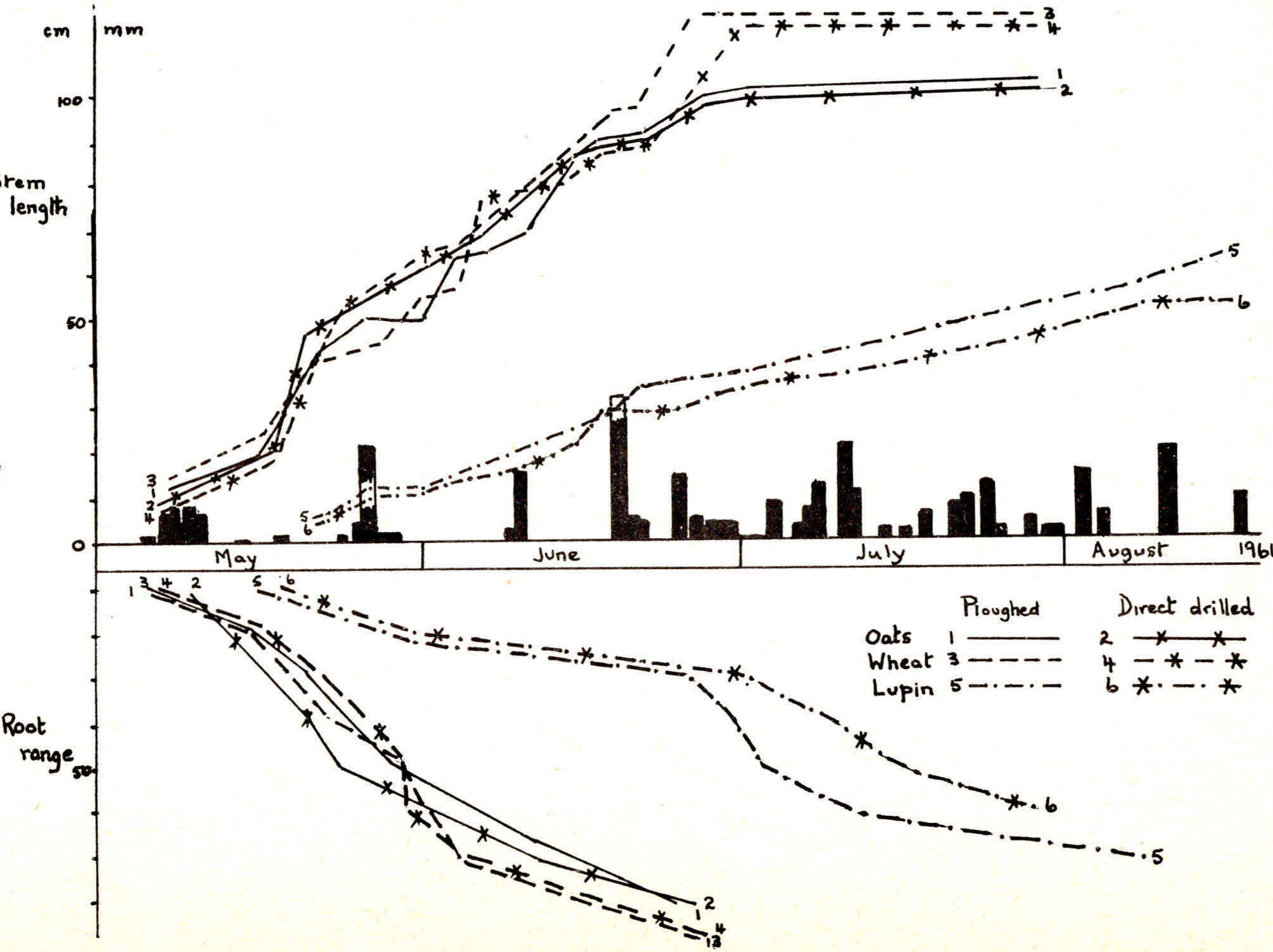
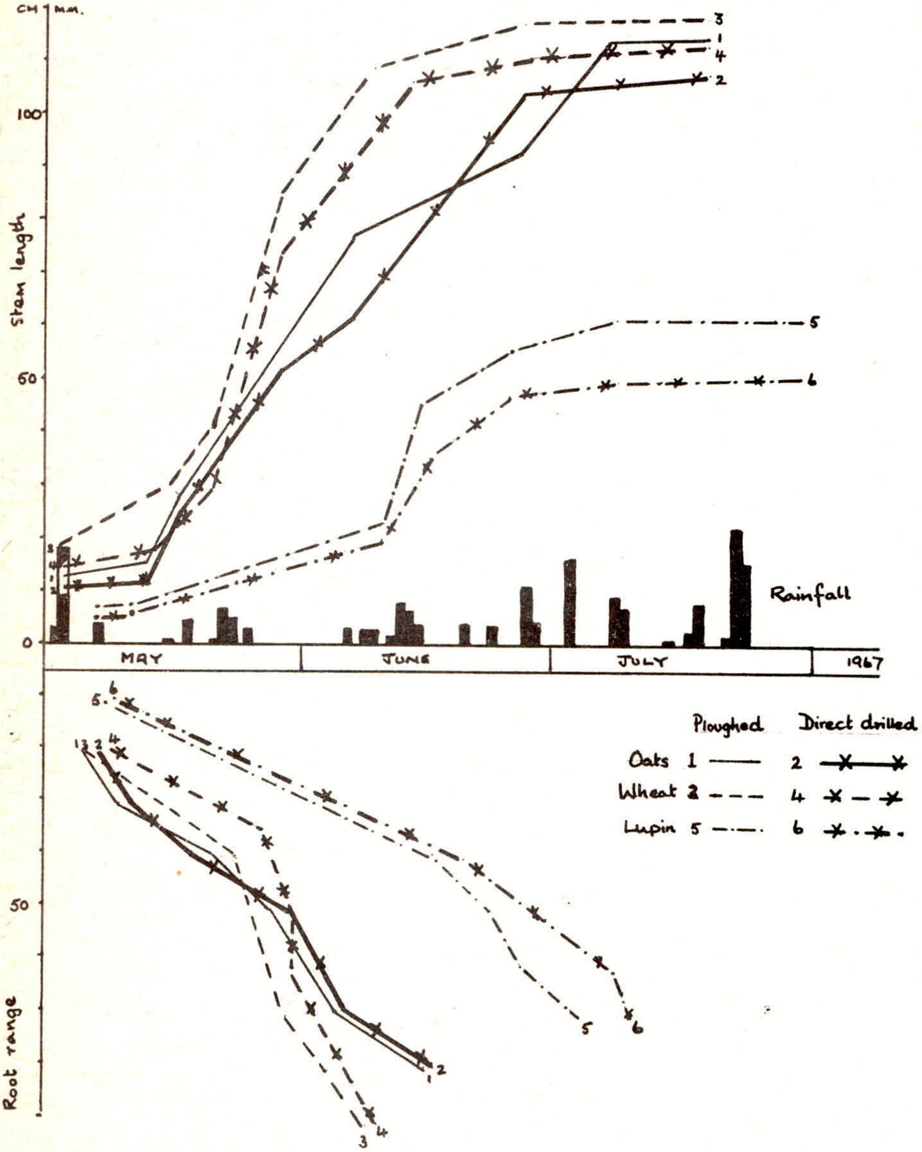


Fig. 1

The growth dynamics of stem and root systems 1966

Fig. 2

The growth dynamics of stem and root systems 1967



As shown by the measurements, in 1966 the cultivation treatments had little effect on the growth of the oat stems either during or by the end of the growing season. The root system of the direct drilled oats penetrated the soil more rapidly than the same crop grown with normal cultivations.

The same results apply to the spring wheat crop, the only difference being that the root system of the direct drilled crop penetrated more slowly down to a depth of 50 cm, taking up to five days longer than the conventional cultivated crop.

Only lupins grew more slowly above and below ground after direct drilling in 1966. In 1967 no significant differences were observed in the growth rate above-ground or below-ground of the oats: slight differences were seen in the winter wheat, and once again greater ones in the lupin crop. Neither rain-fall amounts nor the distribution produced significant differences.

The yields of grain and seed of the test crops are given in table 2.

Table 2

The yields of grain and seed of oats, wheat and lupin t/ha
(acc. to T.Hendrysiak)

	1966		1967	
	Normal Cultivations	Direct Drilled	Normal Cultivations	Direct Drilled
Oats	3.48	3.38	3.19	3.13
Wheat *	2.32	2.13	2.42	2.17
Lupins	0.76	0.59	1.19	0.97

* spring wheat 1966
winter wheat 1967

The figures show that the difference between the two treatments were small.

DISCUSSION

As shown in the results the influence of simplified cultivation on the growth of the above-ground parts and root systems of the test crops has been small.

The grain yields from the direct drilled treatments have remained at the same level as those from normally cultivated crops.

Only the lupin crop seems to show a higher sensitivity to direct drilling with its roots developing more slowly in the initial growth stages. The development of its lateral roots is probably restricted by the indreased compaction of the upper layers of the soil which is reflected in the reduced height of the stem and also in the yield of seed.

However, because of the limited period of investigation so far, and the small number of crops involved, the problem will need further research.

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THE DIRECT DRILLING OF GREEN FODDER CROPS IN WEST WALES

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Summary Information collected from seven farms during 1967 showed that despite some instances of sward recovery after using paraquat, kale and rape crops were successfully established by direct drilling with little competition from annual weeds. Yields were acceptable but could probably have been improved by higher fertiliser usage. Because of firmer ground conditions after direct drilling, crop utilisation was more easily effected. The adoption of the technique would appear to be limited by the availability of direct drilling equipment, and the lack of information on the timing of the fertiliser application.

INTRODUCTION

The direct drilling of green fodder crops was first reported from Aberystwyth by Hammerton and Johnson (1962) who successfully direct drilled rape after paraquat. Hood, Jameson and Cotterell (1964) reported on experiments on establishing crops, including kale, using paraquat as a substitute for ploughing. The advantages of direct drilling green fodder crops such as rape and kale would appear to be that competition from annual weeds is less, that the undisturbed surface withstands poaching better whether the crop is grazed or mechanically harvested, that dairy cows need less washing at milking and that because subsequent cultivations are easier the next crop can be sown earlier. It was, therefore, decided to collect information during 1967 from farms where direct drilling using paraquat had been practised to see firstly if any of these advantages were substantiated, and secondly, whether the technique could arrest the decline in acreage of such crops.

SURVEY METHOD

Although green fodder crops are important on small livestock farms in West Wales, only seven farms direct drilling a total of 33 acres of fodder crops were known to the authors through local district agricultural advisory officers. These were in South Cardiganshire on soils described as medium loams being derived from Ordovician and Silurian Shales and Grits. It was possible to observe a side-by-side comparison of direct drilling compared with ploughing on only two of the seven farms. Data was collected during the autumn of 1967 and is summarised in the Tables.

RESULTS AND DISCUSSION

Spraying technique (see Table 1)

On six out of the seven farms, the swards were grazed before the regrowth was sprayed. Only on one farm (no. 3) was the field cut for conservation. Despite the comparatively low rates of paraquat and low volumes of water used and variations of 4 to 14 days between spraying and drilling, only in two cases was the sward control regarded as unsatisfactory. In one case (farm no. 6), despite using 1½ lb ai/ac, sward control was poor. This could in part be explained by a spring application of farmyard manure which shielded the sward from the herbicide. On another farm (no. 3), there was a marked improvement in the degree of sward kill achieved by an evening, as opposed to a morning, application of paraquat. On all farms, plants which recovered rapidly after spraying included the perennial weeds such as common dock (*Rumex obtusifolius*), creeping thistle (*Cirsium arvensis*), and also cocksfoot (*Dactylis glomeratus*) and white clover (*Trifolium repens*).

Table 1.

Herbicide and fertiliser usage for direct drilled green fodder crops

Farm	Pasture type	Paraquat lb ai/ac	Water gal/ac	Crop	Fertiliser usage units/ac		
					N	P_2O_5	K_2O
1	permanent	$\frac{3}{4}$	10	Rape	70	38	38
2	4 year ley	1	30	Rape	73	40	40
3	4 year ley	1	20	Thousand head	124	56	56
4	permanent	1	20	Maris Kestrel	105	70	—
5	3 year ley	$1\frac{1}{4}$	40	Thousand head	80	56	56
6	permanent	$1\frac{1}{2}$	40	Thousand head	102	75	50
7	1 year ley	1	20	Marrowstem	60	33	33

Drilling technique (see Table 1)

The triple-disc drill* which was used on farms 1 to 5 inclusive worked well on soft ground, but when the soil was stony, penetration was uneven and on one farm additional weights had to be used. With the Contravator,+ which was used on farms 6 and 7, because of its power-driven tines, no penetration problems arose, but difficulty was experienced in covering the seeds owing to the excessively wet soil. On four of the five farms using the triple-disc drill, rolling was carried out to close the grooves and cover the seeds. Seed rates varied from 4 to 6 lb/ac but with the triple-disc drill chick crumbs were used as a diluent to achieve low sowing rates. The total amount of nitrogen applied when drilling the crops varied between 60 and 124 units/ac. This, however, did not include nitrogen applied to the preceding grass crop, which could have increased the total amount of nitrogen actually available.

Despite the advantage of using up to 200 units of nitrogen as shown by Jeater and McIlvenny (1968), farmers in this survey did not use extra nitrogen on direct drilled green crops. Nevertheless, farmers were satisfied with the crop yields which were produced. Data on plant populations and yield were available from only two farms (nos. 6 and 7) in the survey, and these are summarised in Table 2.

Table 2.

Plant populations and harvested yield of direct drilled kale

Farm	Crop	Plant population (no/ft^2)	Plant population (no/ac)	Yield fresh weight (tons/ac)	Yield dry matter (lb/ac)
6	Thousand head kale	3.0	130,680	12.4	4356
7	Marrowstem kale	2.2	98,000	19.4	6050

*Developed by Plant Protection Ltd., and marketed by CBH Marketing Services Ltd.

+Developed and marketed by "Sisis" (Macclesfield) Ltd.

Although on farm 7, the plant population of $2.2/ft^2$ fell to $1.4/ft^2$ at harvest, this was still sufficient to give an acceptable yield (19.4 tons/ac) and enable the marrowstem kale to produce thick succulent stems. The direct drilled kale did, however, suffer from one disadvantage in that plants had less root support and lodged more easily leaving distorted stems in contact with the ground which were more susceptible to slug damage and rotting. Comparable yields of kale grown on the same farm after ploughing were 18.5 and 15.9 tons/ac for farms 6 and 7 respectively.

Establishment operations

Compared with kale established after ploughing, there were no annual weed control problems after direct drilling, because there was insufficient soil disturbance to encourage weed seed germination. Further weed control measures were, therefore, not required. The amount of tractor work necessary to establish the green fodder crops was reduced by half (Table 3) mainly because of the elimination of the time-consuming ploughing operation.

Table 3.

Establishment operations for green fodder crops (tractor hours/ac)

Operations	Traditional method	Direct drilled method
Ploughing	3.2	-
Harrowing and discing	1.5	-
Rolling	0.5	0.4
Spraying	-	0.5
Fertiliser application	0.25	0.3
Sowing	0.5	1.2
Total	5.95	2.4

Utilisation

On all farms, the green crops were grazed in situ, but with direct drilled crops there was a visible reduction in soil damage in wet periods with fewer hoof marks and cleaner stock. On one farm (no. 7), an attempt was made to check on the degree of compaction of the soil surface between ploughed and direct drilled crops by using the Proctor needle** to obtain penetrometer measurements of soil density. At the same time, soil core samples were taken to examine other physical features by estimating moisture content and assessing texture.

These results (Table 4) show that neither moisture content nor texture based on stone and gravel content was significantly different, but there was a highly significant difference in the soil density between the two areas. This difference could explain the advantage of an undisturbed surface for supporting the grazing animal, or harvesting machinery.

This brief survey illustrates some of the advantages of direct drilling green fodder crops, but also highlights the practical problems which occur when a new technique is undertaken on a farm scale. Provided sward control is effective, and that the livestock farmer has access to suitable direct drilling equipment, there would appear to be a considerable future for the technique for establishing green fodder crops whether grazed in situ, or harvested by machine, but further experimental work needs to be done on the quantity and timing of fertiliser application for such crops.

** See Penetrometer Measurements, Methods of Soil Analysis, Agronomy No. 9, American Society of Agronomy, Wisconsin, U.S.A., 1965.

Table 4.

A physical analysis of the soil on direct drilled and ploughed areas at harvest

	Direct drilled	Ploughed	t	Significance
Mean pressure to 6" depth (lb penetration)	138.2	54.94	18.1	$p < 0.01$
Moisture content (%)	30.3	33.4	1.87	N.S.
Stone and gravel content (% by weight)	35.1	29.8	2.14	N.S.

Acknowledgments

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DIRECT DRILLING OF CEREALS, TRIALS 1967/1968

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Summary A further trial in 1967 confirmed earlier findings that where direct drilled winter wheat follows a ley there is a slight yield increase with increasing rates of paraquat in the range 1·0 to 2·0 lb/ac. However when following another cereal crop increasing the rate of paraquat in the range 0·5 - 1·5 lb/ac. did not affect the final yield.

For direct drilled spring barley autumn application of paraquat was superior to spring application where *Agrostis stolonifera* was present but was not critial when *Poa trivialis* was the main weed.

On well drained soils there was no marked yield advantage following the use of higher than normal seed rates for direct drilled cereals.

A single top dressing of spring nitrogen was as effective as split applications on direct drilled winter wheat.

INTRODUCTION

The factors affecting direct drilling were reviewed at the 8th British Weed Control Conference (Jeater 1967). Since then a further series of trials have been conducted in Southern England on couch free well drained soils to obtain further data on

(1) Rates and times of paraquat application

(2) Effect of Seed rate

(3) Timing of spring nitrogen to winter wheat

METHOD AND MATERIALS

All trials had a randomised block design with either four or five replicates. The plot size was 50 yds x 4 yds. The paraquat was applied with a Land Rover mounted sprayer delivering 20 gal/ac at 30 psi. Crops were drilled with an experimental mounted triple disc machine.

RESULTS

Time and Rate of Paraquat Application

Winter Wheat

The preliminary data referred to direct drilled winter wheat following pasture. This investigation was continued in 1967 and was extended to winter wheat following cereals.

In the first trial S24 Perennial Ryegrass was cut prior to spraying on 17th September 1966. Champlein was drilled on 25th October and a satisfactory stand was established. Over winter hares grazed the trial area and hence the spring nitrogen top dressing was split, half being applied at the end of February and the rest at the end of April. Yield data are given in Table 1.

Table 1.

Direct drilled winter wheat following grass
Yield cwt/ac (adjusted to 85% dry matter)

Spring Nitrogen Units/ac	Paraquat lb/ac 1·0	1·5	2·0	Mean
40	28·0	28·4	30·1	28·8
80	38·9	37·3	37·5	37·9
120	39·2	39·9	41·8	40·3
Mean	35·4	35·2	36·1	

Standard error (single plot)	± 1·3
Coeff of variation	3·6%
Sig. diff. P = 0·05	1·9

These data are in line with previous results from this crop transition. There was a marked yield response at all levels of paraquat by increasing the level of spring nitrogen from 40 to 80 units/ac and a further response to 120 units/ac at the upper two levels of paraquat.

The biggest yield response from increasing rates of paraquat was at 120 units nitrogen/ac but even here the increase following 2 lb/ac paraquat compared with 1 lb/ac was only 2·6 cwt/ac.

The other two trials followed cereals. The straw was removed to expose the stubble weeds to the paraquat and to ensure that loose trash was not a problem at drilling. Good stands were establised and the crops overwintered well. Spring nitrogen top dressing was applied on 17th April. The yield data are given in Table 2.

Table 2

Direct drilled winter wheat following cereal
Yield cwt/ac (adjusted to 85% dry matter)

Spring Nitrogen Units/ac	Paraquat lb/ac 0·5	1·0	1·5	Mean		
Trial 1						
40	39·0	37·6	37·4	38·0	SE single plot	± 2·1
80	45·5	44·4	46·1	45·4	Coeff. of variation	4·7%
120	45·0	46·0	47·5	46·2	Sig. diff. P=0·05	3·0
Mean	43·2	42·7	43·7			
Trial 2						
40	34·3	36·1	35·3	35·2	SE single plot	± 1·8
80	34·9	35·4	35·7	35·4	Coeff. of variation	5·2
120	32·2	32·5	32·2	32·3	Sig. diff. P=0·05	2·6
Mean	33·8	34·7	34·4			

In neither trial was there any significant yield difference following any of the paraquat rates at any level of spring nitrogen top dressing.

There was a marked response to spring nitrogen in the first trial up to 80 units/ac at all rates of paraquat. At the second site however there was no yield increase above 40 units/ac and a significant decrease in yield at 120 units/ac compared with 40. This field grew lucerne from 1962-65 and the residual soil nitrogen probably affected the response of this second wheat crop to fertilizer nitrogen.

Spring barley

Both trials followed spring barley and straw was removed after harvest. Paraquat was applied to different plots at three times, November January and February or March. The crop was direct drilled in March. At the first site *Agrostis stolonifera* was the main weed and at the second it was *Poa trivialis*.

At both sites a satisfactory crop was established and hormone spraying gave a good control of broad leaved weeds.

In the first trial there was a marked difference in the control of *Agrostis stolonifera* dependent on the time and rate of application of paraquat.

Table 3.

Direct drilled spring barely rate and time of paraquat application. Estimated percentage ground cover of weed grasses on 2nd May,1967

Paraquat lb/ac	Date of Application 10.11.66	4.1.67	7.3.67
0·5	4·3	15·3	22·0
1·0	3·0	5·3	9·0
1·5	1·3	2·3	6·3

This was reflected in the highest yields being reached after November spraying and the lowest after March applications. The yield following 0·5lb paraquat/ac applied in November was similar to that following 1·5lb/ac applied in March.

At the second site where Poa trivialis was the main weed neither time nor rate of paraquat application had any significant affect either on the degree of weed control nor on the ultimate yield. Assessment of percentage grass weed cover in May variedfrom 0·25 - 3·5 The yield data are given in Table 4.

Table 4.

Direct drilled spring barley rate and time of paraquat application
Yield cwt/ac (adjusted to 85% dry matter)

Paraquat	Date of application							
lb/ac	Trial 1 Agrostis stolonifera				Trial 2 Poa trivialis			
	10.11.66	4.1.66	7.3:67	Mean	29.11.66	5.1.67	13.1.67	Mean
0·5	36·8	33·5	31·9	34·1	35·9	35·1	35·7	35·8
1·0	39·1	37·6	35·4	37·4	35·8	37·3	36·5	36·5
1·5	40·4	38·2	35·6	38·1	36·6	36·5	36·5	36·5
Mean	38·8	36·4	34·3		36·1	36·5	36·2	

	Trial 1	Trial 2
Standard error	± 1·1	± 2·0
Coff. of variation	3·0	5·6
Sig. diff.P=0·05	2·2	Not sig.

Seed rate

A preliminary trial at Jealott's Hill with direct drilled winter wheat showed a higher yield following a seed rate of 2·0 cwt/ac compared with 1·5 or 1·5 cwt/ac. This investigation was extended in 1967 and 1968 with trials on both winter wheat and spring barley.

Winter wheat

In 1967 three trials were carried out in Southern England. Increasing the seed rate led to an increase in the number of plants initially established. Table 5.

Table 5.

Seed rate. Effect on plant establishment 1967
Average number of plants established per yard row

Trial	Seed rate cwt/ac			
No.	1·0	1·5	2·0	2·5
1	24·1	37·9	48·5	
2		39·2	49·2	53·3
3		36·8	45·3	56·2

In the first trial lodging stated in June and was severe by harvest especially at high levels of nitrogen. In the other two trials no lodging occurred. The yield data are given in Table 6.

Table 6.

Seed rate. Effect on yield 1967
Yield cwt/ac (adjusted to 85% dry matter)

Units Spring Nitrogen/ac	Seed rate cwt/ac Trial 1 1·0	1·5	2·0	Mean	Trial 2 1·5	2·0	2·5	Mean	Trial 3 1·5	2·0	2·5	Mean
40	40·2	35·0	37·6	37·6	34·1	34·7	36·9	35·3	27·8	27·9	28·5	28·0
80	43·1	40·7	33·7	39·2	39·6	40·5	41·1	40·4	33·4	35·7	35·8	34·9
120	40·6	38·7	37·5	38·9	42·3	43·6	47·1	44·3	35·6	35·1	37·6	36·1
Mean	41·3	38·1	36·3		38·7	39·6	41·7		32·3	32·9	34·0	
Standard error (single plot)	± 3·2				± 1·5				± 2·4			
Coeff of variation	8·2%				3·7%				7·3%			
Sig. diff. P=0·05	4·6				2·2				3·5			

Where lodging occurred in the first trial, increasing the seed rate generally led to a decrease in yield at all levels of nitrogen. In the other two trials increasing the seed rate generally led to higher yields but usually these were not statistically significant.

A further three trials were carried out in 1968. As in the previous year increasing the seed rate led to higher initial plant establishment. Table 7

Table 7.

Seed rate effect on plant establishment 1968
Average number of plants established per yard row

Trial No.	Seed rate cwt/ac 1·0	1·5	2·0	2·5
1	25·4	35·6	50·1	56·1
2	28·4	40·0	53·5	65·5
3	24·0	35·8	47·8	55·9

Very slight lodging occurred in the first trial with 100 units nitrogen/ac at the top two seed rates. In the second trial lodging occurred at this level of nitrogen on all but the lowest seed rate, whilst in third trial severe lodging was present on these three treatments. Slight lodging was present at the lowest seed rate with 100 units of nitrogen and with 50 units of nitrogen and with 50 units of nitrogen at the top two seed rates in this third trial. These differences were reflected in the grain yield. Table 8.

TABLE 8

Seed Rate effect on yield 1968
Yield cwt/ac (adjusted to 85% dry matter)

Trial No	Units Spring Nitrogen	1·0	1·5	2·0	2·5	Mean	Standard Error	Variation	Sig.Diff. P=0·05
1	50	39·5	41·4	40·5	39·9	40·3			
	100	38·4	40·4	38·2	39·0	39·0	± 1·1	2·8%	1·6
	Mean	38·9	40·9	39·3	39·4				
	50	41·1	39·1	39·2	39·5	39·7			
2	100	39·3	38·0	36·1	34·2	36·9	± 2·1	5·5%	3·1
	Mean	40·2	38·6	37·6	36·9				
	50	42·7	45·0	40·6	39·5	42·0			
3	100	39·6	37·9	36·2	30·5	36·1	± 2·4	6·2%	3·5
	Mean	41·2	41·5	38·4	35·0				

In the first trial where lodging was slight the highest yields were obtained from a seed rate of 1·5 cwt/ac.

The highest yields at both levels of nitrogen were obtained from a seed rate of 1·0 cwt/ac in the second trial. The lowest yields were obtained where lodging was most severe when the highest seed rates were combined with the higher level of nitrogen.

The yields following the lower nitrogen level were always significantly better than those obtained with 100 units nitrogen/ac in the third trial. The highest yield of all was obtained from a seed rate of 1·5 cwt/ac.

In all these trials there was no yield advantage following the use of highest seed rates.

Spring Barley

Three trials were conducted, two in 1967 and one in 1968. In both years as with winter wheat increasing seed rate gave higher initial plant establishment. Table 9.

TABLE 9

Seed rate effect on plant establishment
Average number of plants established per plant row

Trial No	Seed rate lb/ac 110	150	190
1	29·8	44·0	51·4
2	36·1	50·4	65·3
3	35·1	52·6	63·2

In the first trial there was in general an increase in yield with increasing seed rate but in the other two there was either no marked difference or a reduction in yield with increasing seed rates. In 1968 the yield reduction was associated with severe lodging leading to an interaction between seed rate and nitrogen rate. Table 10.

TABLE 10

Seed rate effect on yield
Yield cwt/ac (adjusted to 85% dry matter)

Trial No	Units Spring Nitrogen/ac	Seed rate lb/ac 110	150	190	Mean	Standard error	Coeff. of variation	Sig. diff. P=0·05
	40	34·3	37·2	39·4	37·0			
1	80	33·9	36·8	40·8	37·2	± 1·0	2·8%	1·5
	120	32·6	35·6	35·1	34·4			
	Mean	33·6	36·5	38·4				
	40	36·4	35·6	36·8	36·2			
2	80	40·6	41·6	40·9	41·0	± 2·0	5·0%	2·9
	120	41·4	42·0	40·6	41·4			
	Mean	39·5	39·7	39·4				
	40	35·5	36·4	36·7	36·3			
3	80	38·1	39·3	36·3	37·9	± 2·0	5·5%	2·9
	120	36·9	33·2	30·4	33·5			
	Mean	36·8	36·3	34·5				

Winter wheat - timing of spring nitrogen top dressing

Preliminary investigations showed no advantage from split applications of spring nitrogen top dressing compared with a single application. A similar pattern emerged in 1967. Table 11.

TABLE 11

Winter Wheat - effect of time of application of spring nitrogen
Yield cwt/ac (adjusted to 85% dry matter)

Trial No	Control no Nitrogen	Single applications Mid March	Early April	Mid April	Split applications Early March Early April	Early March Early May	Mid March Mid April
1	37·0	41·3	46·6	47·6	39·3	44·1	
2	24·2	41·4		44·1			43·8

Sig. diff. P = 0·05 Trial 1 4·0 Trial 2 3·9

Levels of 80 and 120 units/ac were used in these trials with no response to the higher level hence the data are presented as a mean of the two rates. In neither trial was any advantage shown by split applications over single applications. A single application in mid April gave the highest yield in both trials.

DISCUSSION

These additional data have helped to confirm and to quantify the data and ideas promulgated in the review at the previous Weed Control Conference.

It is evident that paraquat is more effective when applied in the autumn and winter than when applied in the spring. Hence even when spring barley is to be sown, spraying should be done in the autumn or early winter rather than leaving it until the spring especially when Agrostis stolonifera is present.

Where cereals following cereals, rates of 0·5 - 1·0 lb/paraquat/ac have proved effective in these trials both for winter wheat and spring barley. However where winter wheat follows grass, increasing the rate of application has in general led to slightly higher yields.

The data recorded from the seed rate and timing of spring nitrogen trials has shown that providing direct drilling is carried out on soils which are naturally well drained and that good weed control is achieved the general growth of the crops is similar to that after ploughing. This is reflected in the yield data which generally show that no marked advantage was achieved by increasing the seed rate above that normally practised. Equally the optimum timing of spring nitrogen application was similar to that practised on conventionally grown crops.

These data suggest that on well drained soils the plants established after direct drilling are very similar to those established after normal cultivation and hence the general agronomy is similar. However, on soils which have a large proportion of small particles and which are very compacted in the autumn the general growth and development of direct drilled crops is not as goodas that of conventionally grown ones particularly in the case of winter wheat. This may be associated with a poorer initial root development in compacted soils with few large pores for the seminal roots to follow. Cultivating these more compact soils produces a number of large pores which are drained gravitationally allowing water to get away from the developing seedling and at the same time encouraging a more rapid and prolific initial root growth. Where these soils are left in a compacted state root growth is difficult as the soil has to be deformed by the roots and water is held up and produces conditions which are not conducive to the establishment of a vigorous plant. In these cases it may subsequently be necessary to use more nitrogen after direct drilling to compensate for the less vigorous initial growth. This effect was seen in some of the early Jealott's Hill trials on soils which are not considered to be unsuitable for direct drilling. A study of initial root development in cereals after direct drilling may help to explain the problems that have been encountered when direct drilling has been tried on poorly drained soils.

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FURTHER EXPERIMENTS WITH LENACIL AND OTHER HERBICIDES IN STRAWBERRIES

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Summary Repeated annual applications of lenacil at doses of 1 to 4 lb/ac for four years had no adverse effect on the growth or yield of strawberries. A high dose of 6.4 lb/ac applied three weeks after planting and repeated one year later also caused no injury. Six widely planted cultivars showed no significant difference in susceptibility in a pot experiment. The results confirm that lenacil is a useful herbicide for strawberries with a good margin of safety under conditions at Clonroche.

INTRODUCTION

Reports presented at the Eighth British Weed Control Conference showed that lenacil was a promising herbicide for strawberries (Cleary, 1966; Tyson, 1966; Ivens and Clay, 1966). As with other herbicides, further information is desirable on a number of aspects viz:

(1) The effect of repeated application over a number of years;
(2) The effect of accidental overdosing;
(3) The possibility of differences in susceptibility between cultivars.

Two experiments with lenacil, started at the Soft Fruit Research Station, Clonroche in April 1965 (Cleary, 1966) were continued until August, 1968 to obtain information on the effect of repeated applications. Other trials were started in the period 1966 - 1968 to study the effect of high doses of lenacil on strawberries and to ascertain if differences exist between cultivars in their susceptibility to this herbicide.

METHODS, MATERIALS AND RESULTS

Experiment I

This design and first year results of this experiment have been presented (Cleary, 1966). The herbicide treatments (Table 1) were first applied in August, 1965 to the cultivar Gorella and were repeated on the same plots in August, 1966, May, 1967 and April, 1968. Between herbicide applications weeds were controlled on all plots by cultivation.

Crop yields for the three years are presented in Table 1. There were no significant differences between treatments although the yield was slightly lower on plots treated with PH 40-21 (4, 5, 7 - trichlorobenzthiadiazole-2, 1, 3) and simazine. There was no evidence that four annual applications of lenacil, chloroxuron or diphenamid had any adverse effect on the yield compared with cultivated control plots.

PH 40 - 21 caused some leaf injury after applications in all years. Some signs of chlorosis also occurred on plots sprayed with simazine at $\frac{3}{4}$ and 1 lb/ac in April, 1968. Otherwise no treatment had any harmful effects on the plants.

Table 1

Effect of herbicides on yield of cultivar Gorella (cwt/ac)

Treatment	lb/ac	1966	1967	1968	1966 + 1967	1966+67+68
Cultivated control	0	1.3	68.0	79.1	69.3	148.4
Simazine	$\frac{1}{2}$	0.8	67.4	65.6	68.2	133.7
"	$\frac{3}{4}$	0.7	49.5	86.8	50.2	137.0
"	1	0.6	64.3	71.9	64.9	136.8
Chloroxuron	4	1.3	72.4	89.6	73.7	163.2
Diphenamid	4	1.8	78.0	85.1	79.8	164.8
Chloroxuron + diphenamid	2 + 2	2.4	78.4	88.2	80.8	169.0
"	3 + 3	2.0	70.8	79.9	72.7	152.7
Lenacil	1	2.3	75.1	81.3	77.3	158.7
PH 40-21	1	1.0	64.8	64.8	65.8	130.6
"	2	1.1	69.9	65.5	71.0	136.5
"F" test		N.S.	N.S.	N.S.	N.S.	N.S.
S.E. (df = 20)		± 0.42	± 6.27	± 9.22	± 6.33	± 13.10

Experiment 2

Similar results were obtained in an experiment in which lenacil was applied at 0, 1, 2 and 4 lb/ac on the cultivar Templar in August, 1965, 1966, 1967 and 1968. Crop yields (Table 2) and plant measurements showed that none of the treatments had any harmful effect on the crop.

Table 2

Effect of repeated applications of lenacil on yield of cultivar Templar (cwt/ac)

Lenacil lb/ac	1967	1968
0	115.7	110.9
1	119.0	121.8
2	118.0	119.4
4	124.9	125.4
"F" test	N.S.	*
S.E. (df = 3)	± 20.4	± 14.95

Experiment 3

An experiment was carried out to test the effect of high doses of lenacil on cultivar Cambridge Favourite. The strawberries were planted 18 in. apart in drills 34 in. apart on 3 April, 1967. The herbicides listed in Table 3 were applied on 25 April, 1967 and 29 March, 1968. The design used was a randomised complete block with five replicates. Plot size was 38 x 6 ft. Simazine and chloroxuron were included for comparison purposes. On 4 August, 1967 all plots were rotavated and the drills were earthed up. On 10 August, 1967 simazine was applied at $1\frac{1}{2}$ lb/ac to all plots. Paraquat was used as a directed spray to control runners in the alleys of herbicide-treated plots on 19 January and 30 August, 1968. Weed counts were made on 8 - 9 August, 1968.

There was no sign of any herbicide damage throughout the period of the experiment. Yield results are presented in Table 3.

Table 3

Effect of herbicides on yield of cultivar Cambridge Favourite (cwt/ac).

Treatment	lb/ac	1967	1968
Cultivated control	0	4.4	132.7
Lenacil	1.6	4.1	145.4
"	3.2	4.4	121.7
"	6.4	4.1	131.8
Simazine	$\frac{3}{4}$ + charcoal dip at planting	4.4	145.7
Chloroxuron	5	4.5	131.5
"F" test		N.S.	N.S.
S.E. (df = 20)		± 0.35	± 8.66

All herbicide treatments gave much better weed control than did cultivations, but lenacil 1.6 lb/ac and chloroxuron gave incomplete control of Poa annua. Lenacil at 6.4 lb/ac gave excellent control of all species except Viola arvensis. Chloroxuron at 5 lb/ac was ineffective against Anagallis arvensis.

Experiment 4

An experiment was designed to examine the susceptibility of six strawberry cultivars to lenacil and other herbicides. The six cultivars were Cambridge Vigour, Cambridge Favourite, Gorella, Senga Sengana, Talisman and Templar.

Runners of six cultivars were lifted from runner beds at Clonroche and were graded accurately for size on 20 February, 1968. On 21 February, 75 evenly sized plants of each variety were planted in pots sized 6 in. x 6 in. The potting material used was top soil of the Clonroche series, and had a mechanical analysis of 24% coarse sand, 11% fine sand, 37% silt, 28% clay and 3.4% organic carbon. The plants were grown on in an unheated glasshouse until 22 March when the following treatments (lb/ac) were applied to each variety :-

Lenacil 0, 1, 2, 4, 8; simazine 0, $\frac{1}{4}$, $\frac{1}{2}$, 1, 2 and terbacil 0, $\frac{1}{4}$, $\frac{1}{2}$, 1, 2.

Treatments were applied to single pots using a randomised factorial design with five replications. The plants were grown in the glasshouse until 4 May and outside until 24 June. The plants were then harvested by cutting at soil level and fresh weights were recorded (Table 4).

Between the time of spraying and time of harvesting all symptoms of herbicide damage were recorded and the plants were periodically rated for herbicide damage. First signs of damage occurred on 1 April on the plants receiving the higher doses of terbacil. The damage took the form of interveinal and marginal blackening of the leaves. Damage showed up on the plants receiving simazine and lenacil on 10 April. The foliage symptoms caused by simazine were similar to those caused by terbacil. Lenacil resulted in vein clearing initially and later the veins turned yellow and the leaves became mottled.

The damage in all treatments became progressively worse until by 22 April many of the terbacil-treated plants had died. By 26 April some of the simazine and lenacil-treated plants were also dead. Subsequently the less severely damaged plants began to recover while the more severely damaged plants continued to deteriorate. After the end of May no further plants died.

Shortly after application the damage caused by terbacil and lenacil was more severe on Gorella and Favourite than on the other cultivars. These early cultivars were growing more strongly than the others at that time and this may account for the greater damage.

Table 4

Effect of herbicides on fresh weight of 6 strawberry cultivars (gm/pot)

Variety	Simazine					
	0	¼	½	1	2	Mean
Cambridge Vigour	10.1	10.1	7.5	8.1	3.8	8.2
Cambridge Favourite	12.3	14.4	11.9	8.8	0.3	9.4
Gorella	13.9	14.6	10.8	7.1	3.0	9.5
Senga Sengana	10.3	14.0	10.7	7.4	2.0	9.3
Talisman	11.2	17.4	16.3	11.1	0.7	12.1
Templar	13.2	10.9	10.7	7.9	1.2	8.6
Mean	12.31	13.55	11.31	8.40	1.81	9.48

Variety	Lenacil					
	0	1	2	4	8	Mean
Cambridge Vigour	10.1	8.3	6.9	7.4	1.5	7.1
Cambridge Favourite	12.3	9.4	9.0	0	0	6.3
Gorella	13.9	15.3	5.0	1.5	0.8	7.2
Senga Sengana	10.3	14.8	9.0	1.9	0	7.1
Talisman	11.2	13.7	14.3	6.6	1.5	10.0
Templar	13.2	12.5	11.1	6.5	2.1	9.1
Mean	12.31	12.34	9.20	4.01	0.99	7.81

Variety	Terbacil					
	0	¼	½	1	2	Mean
Cambridge Vigour	10.1	13.9	6.0	0	0	5.5
Cambridge Favourite	12.3	6.0	0.7	0.1	0	3.7
Gorella	13.9	13.9	2.4	0.2	0	6.6
Senga Sengana	10.3	12.1	4.3	0.3	0	5.1
Talisman	11.2	16.2	2.8	0.1	0	6.5
Templar	13.2	12.8	1.2	0.1	0	5.7
Mean	12.31	12.49	2.92	0.10	0	5.52
"F" test Cultivars (C)			***	S.E.		± 0.79
Herbicides (H)			***			± 0.56
Doses (D)			***			± 0.46
[1] H x D			***			± 0.74

[1] The H x D two factor interaction was highly significant when all 3 herbicides were compared at the 3 lower doses. This was the only interaction found significant.

Two analyses of variance were carried out on the fresh weight data. Due to severe damage caused by the two higher levels of terbacil an analysis was carried out omitting these two levels in all three chemicals. The Herbicide x Dose interaction was highly significant. The $\frac{1}{2}$ lb dose of terbacil severely reduced the fresh weight compared with the only slight reductions by lenacil (2 lb) and simazine ($\frac{1}{2}$ lb). In the second analysis terbacil was omitted and an analysis was carried out on the 4 lower levels of simazine and lenacil. The Herbicide x Dose interaction did not recur. In neither analysis were any of the interactions involving variety found to be significant. Although Gorella and Cambridge Favourite showed slightly more damage than the other cultivars when treated with the lower doses of lenacil, there was no evidence of any marked difference in susceptibility. The effect of cultivar, herbicide and dose was highly significant in both analyses.

DISCUSSION

Although lenacil caused some injury to strawberries in the pot experiment when used at doses above 2 lb/ac, no damage to plants in the field has been recorded under conditions at Clonroche.

Lenacil would be expected to be more phytotoxic where plant roots are confined in pots and the results confirm that this herbicide is a relatively safe one for strawberry growers. The regrowth of susceptible weeds e.g. *Stellaria media* within a few months of treatment with lenacil indicates that this herbicide is much less persistent in the soil than simazine. It is unlikely then that damage would result from repeated annual applications of normal herbicidal doses. This is confirmed in Experiments 1 and 2 by the absence of any injury where repeated doses were used for four years.

The good tolerance of strawberries to lenacil under conditions at Clonroche is shown more clearly in Experiment 3 where a dose of 6.4 lb/ac caused no damage even when applied within three weeks of planting the runners.

The results of Experiments 1 and 3 showed that, at normal herbicidal doses lenacil was generally more effective than chloroxuron and less effective than simazine. The importance of applying lenacil under moist soil conditions has been shown at Clonroche (Cleary, 1968). Application when the soil is dry probably accounts for the occasional reports of lack of weed control by this herbicide.

Lenacil controls many of the most common weeds of strawberries, e.g. *Poa annua*, *Stellaria media* and *Polygonum aviculare*. It is, however, more expensive and less effective than simazine and is not likely to replace simazine as the major herbicide for strawberries in Ireland. Nevertheless, the good margin of safety shown by lenacil in these field experiments and the absence of any obvious differences in susceptibility between varieties confirm that it is a useful herbicide for young runners and for application in the spring when treatment with simazine is risky.

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TRIALS ON THE SELECTIVITY OF LENACIL IN STRAWBERRIES

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Summary Five replicated trials were carried out on established strawberries and four on newly planted crops. In each case lenacil at 1.6, 2 and 4 lb a.i./ac was compared with chloroxuron at 4 or 5 lb a.i./ac. The weed control from lenacil at 1.6 and 2 lb a.i./ac, although usually satisfactory, tended to be more variable than from chloroxuron probably due to dry weather. At 1.6 and 2 lb a.i./ac lenacil did not affect either established or new plantings, but 4 lb a.i./ac caused a slight check to the new plantings in two trials.

On the established crops the yields were not affected by any of the treatments.

INTRODUCTION

Trials by Hughes (1966), Ivens (1966) and Tyson (1966) showed lenacil to be a very promising herbicide for established strawberries. Although yields were taken by Ivens (1966) in one replicated trial and by Tyson (1966) in several farmer trials it was considered desirable to have further yield information before a firm recommendation could be made for fruiting beds.

Allott (1966) had also shown lenacil to be very promising on newly planted runners at Loughgall. Additional evidence was, however, considered desirable. Hence further trials were planned for the 1967 season on both established strawberries and newly planted runners.

METHOD AND MATERIALS

In the spring of 1967 nine trials were laid down to compare lenacil at 1.6, 2 and 4 lb a.i./ac and chloroxuron at 4 or 5 lb a.i./ac. Five trials were on established crops planted at least one year previously and four on crops planted within 4 months of spraying. The plots were 2 rows wide by 10-15 yd long with four replications. The treatments were applied between mid-February and mid-April 1967 at 20 gpa. Four of the five trials on established beds were taken to yield. In two of the yield trials the variety was Cambridge Favourite, while the remaining varieties were Templar and Red Gauntlet.

RESULTS

Established crops

(a) Effect on weeds In general the control of weeds by lenacil was fair to excellent although it was disappointing at one site with 1.6 and 2 lb, where light infestations of *Urtica urens*, *Lamium purpureum*, and *Veronica hederifolia* were not well controlled. On another site some *Veronica hederifolia*, *Tripleurospermum* maritimum ssp. inodorum, Polygonum aviculare and Senecio vulgaris survived but had obviously received a greater check from 4 lb lenacil than from the lower doses. In this trial a few Galium aparine, Veronica hederifolia and Tripleurospermum maritimum ssp. inodorum also survived application of 5 lb chloroxuron. On the remaining two trials all treatments gave excellent weed control.

(b) Effect on crop Several assessments were carried out during the season but there were no signs of any treatment affecting the crop. At one site there was slight interveinal chlorosis on rooting runners but these symptoms had disappeared by mid-July.

(c) Yields Four of the five trials were taken to yield. In some cases as many as eight pickings were carried out over a period of three weeks. The yields, as given in Table 1, do not appear to have been affected by any of the treatments.

Table 1

Yields of strawberries (tons/ac) after treatment with lenacil or chloroxuron

Location	Lenacil 1.6 lb	Lenacil 2 lb	Lenacil 4 lb	Chloroxuron 4 lb	Chloroxuron 5 lb	Untreated
Easthorpe, Essex	5.02	4.99	4.30	-	5.01	4.65
Holt, Wrexham	2.49	2.18	2.37	2.67	-	2.12
Sutton Bridge, Lincs	4.85	4.77	5.25	-	4.80	-
Feering, Essex	8.25	8.57	8.72	8.85	-	-

On the trial at Easthorpe the individual yields from each picking were compared and it was found that none of the treatments affected the time of attaining the final yield.

Newly planted strawberries

Effect on weeds In one of the four trials none of the treatments gave satisfactory weed control possibly due to the weeds being established before spraying. In the second and third trial chloroxuron at 4 lb gave better control of Veronica hederifolia, Galium aparine and Senecio vulgaris than lenacil at 1.6 or 2 lb, while lenacil gave better results than chloroxuron on Poa annua especially at 4 lb. In the fourth trial lenacil at all doses was better than chloroxuron on Senecio vulgaris and Sonchus oleraceus.

Effect on crop In one trial there was a slight loss of vigour where lenacil was used at 4 lb. In another trial there was slight veinal chlorosis on a few plants where lenacil was used at 4 lb. There was no effect on the crop in any of the trials from chloroxuron at 4 lb or lenacil at 1.6 and 2 lb.

DISCUSSION

Weed control from lenacil at 4 lb was equal to chloroxuron at 4 or 5 lb in all trials and was better in two trials. Lenacil at 1.6 or 2 lb generally did not give quite as good control as chloroxuron at 4 or 5 lb. This may have been due to the dry soil and weather conditions experienced in some of the trials where lenacil seemed more dependant on soil moisture than chloroxuron. The control of Galium aparine was variable with both chemicals. Lenacil at 1.6 or 2 lb tended to be better than chloroxuron at 4 or 5 lb on Poa annua, Senecio vulgaris and Sonchus oleraceus while chloroxuron at these doses tended to be better on Veronica hederifolia, Urtica urens, and Lamium purpureum.

The main reason for including lenacil at 4 lb was to investigate its effect on the crop. It was very selective on established strawberries even at the high dose of 4 lb which had no effect on yield. On newly planted strawberries lenacil at 1.6 or 2 lb was selective to the crop, but at 4 lb there were slight effects on the plants in two of the four trials.

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THE TOLERANCE OF NEWLY PLANTED STRAWBERRIES TO CERTAIN SOIL-ACTING HERBICIDES

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Summary Experiments are described in which a number of soil-acting herbicides were applied shortly after spring planting of the two strawberry cultivars Cambridge Vigour and Templar. The value of an activated charcoal root dip in the prevention of herbicide injury was also examined. A count of living plants followed by a second herbicide treatment and the subsequent crop yield the following season showed that activated charcoal reduced the toxicity of simazine, atrazine and terbacil (3-t-butyl-5-chloro-6-methyl-uracil) when the chemicals were applied initially at doses of 1.0 lb/ac. It was evident that there was no advantage in using charcoal with lenacil, chloroxuron and EPTC which were non toxic. Terbacil, which will control some simazine resistant weeds, merits further investigation to determine whether doses lower than 1.0 lb/ac will provide an adequate, economical, weed control without crop damage in the absence of a charcoal root dip.

INTRODUCTION

Robinson (1965), Allott (1965), Allott and Hay (1966), Hughes (1966) and others have shown that in many situations of soil and climate simazine is toxic to maiden strawberries unless the roots of runners are dipped in activated charcoal before planting. The relatively recent introduction of lenacil, however, has enabled a reasonably adequate weed control to be obtained in newly planted strawberries without the necessity for a charcoal root dip. Whilst simazine is the most widely used herbicide in established strawberry plantations giving an adequate control of most common annual weeds, species such as Polygonum aviculare (knotgrass) and perennials such as Agropyron repens (couchgrass) are not susceptible to doses which are selective to strawberries. Hughes (1966) has shown that knotgrass can be controlled by lenacil which thus has the advantage of selectivity to maiden strawberries and of the ability to control certain simazine resistant weeds. It seemed, however, that the tolerance of strawberries to terbacil should also be examined in view of the ability of this herbicide to control some simazine resistant weeds, including couchgrass, which are not susceptible to lenacil.

The experiments reported in this paper were, therefore, established in March 1967, a time of year when strawberries are particularly susceptible to herbicide damage, to enable the tolerance to terbacil of newly planted runners of the cultivars Cambridge Vigour and Templar to be compared with other more widely used herbicides.

METHOD AND MATERIALS

An experiment was planted in March 1967 using runners of the cultivar Cambridge Vigour which is widely grown in Northern Ireland. Another experiment was initiated at the same time on an adjacent site to examine the tolerance of the cultivar Templar to the same herbicide treatments under Northern Ireland conditions. In accordance with the treatments the roots of runners were dipped in activated charcoal immediately before planting, bundles of twelve runners were treated simultaneously.

Powdered steam activated charcoal was used having an iodine index of 80.5. This represents the weight of iodine (gm) adsorbed by 100 gm of dry activated powder (Robinson 1965).

Simazine, lenacil, terbacil, atrazine, chloroxuron and EPTC were applied two weeks after planting. Due to soil conditions prior to planting EPTC could not be applied then and cultivated into the soil. Herbicides were applied from a knapsack sprayer in 50 gal/ac water.

The plants were not allowed to fruit in 1967 and the treatment effects were assessed by a living plant count in August.

In October 1967 treatments were repeated except that EPTC was replaced by lenacil at 2.0 lb/ac and the terbacil dose was reduced to 0.25 lb/ac from the original 1.0 lb/ac. Further treatments were not applied but freedom from weeds was maintained by the application of lenacil at 1.6 lb/ac to both experiments in April 1968. Crop yields were recorded in 1968. Weeds were scored in July 1967 on a scale from 0 - 5 where 0 = no weeds 5 = weeds dominant.

The soil on the experimental site contained, in the 0 - 2" horizon, approximately 20% coarse sand, 35% fine sand, 10% silt, 20% clay and 10% organic natter as measured by loss on ignition.

The design of each experiment comprised a factorial arrangement of two root treatments (dipped and undipped) x seven herbicides (including an unsprayed control) giving 14 treatment combinations in each block of three replicates. There were 16 recorded plants per plot.

Fertilizer treatment, pest and disease control followed normal practice.

RESULTS

The mean number of living plants in both experiments in August 1967 and the mean crop yield in 1968 are presented in Tables 1 - 2 and 3 - 4 respectively. It is evident from Table 1 that the charcoal root dip technique significantly increased plant survival of both cultivars where simazine, atrazine and terbacil were applied.

Table 1

Mean no. of living plants of two strawberry cultivars following herbicide applications two weeks after spring planting

Cultivar		Cambridge Vigour		Templar	
Root treatment		Charcoal dipped	Undipped	Charcoal dipped	Undipped
Herbicide	lb/ac	Mean no. of living plants			
Unsprayed control		15.66	16.00	14.66	16.00
Simazine	1.0	16.00	12.66	15.33	10.33
Lenacil	1.0	16.00	14.66	14.66	14.00
Terbacil	1.0	15.66	13.00	16.00	11.33
Atrazine	1.0	15.66	11.00	15.00	9.33
Chloroxuron	5.0	16.00	15.33	15.00	14.66
EPTC	5.0	15.66	16.00	15.66	16.00
S.E. of a difference between two means		0.88 (26 d.f.)		1.79 (26 d.f.)	
Variance within treatment means		**		*	

Table 2 shows that simazine and atrazine significantly reduced plant numbers of templar compared to the unsprayed control. Simazine, atrazine and terbacil also reduced plant numbers of Cambridge Vigour. Atrazine was shown to be the most toxic herbicide with respect to both cultivars. The charcoal root dip gave an appreciable protection against herbicide damage to both cultivars (Table 2).

Table 2

Mean no. of living plants of two strawberry cultivars following herbicide applications two weeks after spring planting

Cultivars		Cambridge Vigour	Templar
Herbicide	lb/ac	Mean no. of living plants	
Unsprayed control	-	15.83	15.33
Simazine	1.0	14.33	12.83
Lenacil	1.0	15.33	14.33
Terbacil	1.0	14.33	13.66
Atrazine	1.0	13.33	12.17
Chloroxuron	5.0	15.66	14.83
EPTC	5.0	15.83	15.83
S.E. of a difference between two means		0.62 (26 d.f.)	1.26 (26 d.f.)
Variance within treatment means		**	N.S.
Root treatment			
Dipped in charcoal		15.81	15.66
Undipped		14.09	13.09
S.E. of a difference between two means		0.33 (26 d.f.)	0.68 (26 d.f.)
Variance within treatment means		***	**

Crop yields in Table 3 in general support the plant count data in Table 1 except that there was no significant difference in yield between charcoal dipped and undipped plants of Templar following terbacil treatment. Table 4 shows that atrazine reduced the yield of Templar. The yield of Cambridge Vigour was unaffected by the herbicide treatments. Crop yields again illustrated the value of the charcoal root dip which significantly increased the yield of both cultivars.

Table 3

Mean crop yield of two strawberry cultivars following post-planting herbicide treatments

Cultivar			Cambridge Vigour		Templar	
Root treatment			Charcoal dipped	Undipped	Charcoal dipped	Undipped
Herbicide	Dose lb/ac Spring	Autumn	Mean yield lb/plot			
Unsprayed control	-	-	22.50	25.33	23.47	22.12
Simazine	1.0	1.0	32.79	23.83	27.08	15.89
Lenacil	1.0	1.0	36.00	33.10	26.02	25.68
Terbacil	1.0	0.25	31.35	13.92	26.75	21.75
Atrazine	1.0	1.0	29.58	11.06	22.04	11.83
Chloroxuron	5.0	5.0	26.83	32.93	26.77	24.81
EPTC)	5.0	-	31.51	33.49	20.02	27.00
Lenacil)		2.0				
S.E. of a difference between two means			3.43 (26 d.f.)		3.68 (26 d.f.)	
Variance within treatment means			***		N.S.	

Table 4

Mean crop yield of two strawberry cultivars following post-planting herbicide treatments

Cultivars			Cambridge Vigour	Templar
Herbicide	Dose lb/ac Spring	Autumn	Mean yield lb/plot	
Unsprayed control	-	-	23.91	22.79
Simazine	1.0	1.0	28.31	21.48
Lenacil	1.0	1.0	34.63	25.85
Terbacil	1.0	0.25	22.63	24.25
Atrazine	1.0	1.0	20.32	16.93
Chloroxuron	5.0	5.0	29.88	25.79
EPTC)	5.0	-	32.51	27.51
Lenacil)	-	2.0		
S.E. of a difference between two means			2.43 (26 d.f.)	2.53 (26 d.f.)
Variance within treatment means			***	**
Root treatment				
Dipped in charcoal			30.08	25.73
Undipped			24.81	21.29
S.E. of a difference between two means			1.25 (26 d.f.)	1.27 (26 d.f.)
Variance within treatment means			***	***

Weed scores (Table 5) in July 1967 showed that terbacil and atrazine gave the most satisfactory control of the predominant weeds with simazine slightly less adequate.

Table 5

Mean weed scores following post-planting herbicide applications to two strawberry cultivars

		Cambridge Vigour	Templar
Herbicide	lb/ac	Weed score (mean of 6 replicates)	
Unsprayed control	-	2.81	2.66
Simazine	1.0	1.50	1.16
Lenacil	1.0	1.66	1.66
Terbacil	1.0	0.66	1.16
Atrazine	1.0	0.66	0.66
Chloroxuron	5.0	1.83	1.66
EPTC	5.0	1.83	1.83

Note: Principal weeds on the sites of these experiments were: *Atriplex patula* (orache), *Polygonum aviculare* (knotgrass), *Senecio vulgaris* (groundsel), *Polygonum persicaria* (red shank), *Stellaria media* (chickweed) and *Poa annua* (annual meadow grass).

DISCUSSION

The use of simazine in established strawberry plantations as a post-fruiting or autumn treatment for the control of annual weeds is now an established practice. Established plantations in the spring and newly planted runners however, are susceptible to this herbicide. It has been demonstrated by Robinson(1965), Allott (1965), Allott and Hay(1966) and others that if the roots of runners are dipped in activated charcoal before planting the toxicity of simazine can be substantially reduced. Plant count and crop yield records from the experiments described in this paper confirm the value of this technique. Charcoal dipping, however, necessitates an additional production cost. Hughes (1966) reports that simazine doses of 8 oz/ac can provide a satisfactory weed control at Efford whilst being generally safe to the strawberry plants. At Loughgall this dose would not necessarily provide an adequate weed control consequently a higher dose is preferable and charcoal dipping is essential.

The introduction of lenacil, therefore, appeared to be particularly fortuitous in Northern Ireland. It was shown by Allott & Hay (1966) and Tyson (1966) that newly planted strawberry runners are not damaged by lenacil at unusually high doses even without a charcoal root dip protection. The trials reported in this paper again demonstrate the tolerance of maiden strawberries to lenacil but at lower, more economic, doses. The level of weed control when this herbicide is applied at 1.0 lb/ac, as in these trials, has generally been disappointing. It would seem that higher doses, probably in the region of 2.0 lb/ac, would be preferable to ensure an adequate weed control.

In addition to the greater crop tolerance lenacil has the advantage that it will control some simazine resistant weeds such as *Polygonum aviculare* (knotgrass) and *Atriplex patula* (orache) (Tyson 1966). There would, however, appear to be the necessity for a herbicide which will control these weeds together with simazine susceptible species and certain perennial weeds which occasionally occur in strawberry plantations. Whilst it is accepted that perennial weeds should be removed from a site before strawberries are planted this is not always achieved in practice especially with grass weeds such as <u>Agropyron repens</u> (couchgrass). Consequently the availability of herbicides which will selectively control this and other simazine resistant weeds is likely to be advantageous in some plantations, particularly if such a treatment is more economic than lenacil or the simazine and charcoal combination. It is known that terbacil will control couchgrass at fairly low doses in addition to a fairly broad spectrum of other common weeds. These trials have demonstrated that terbacil is more phytotoxic to strawberries than lenacil at an equivalent dose but that terbacil gave a better weed control. The evidence suggests, however, that this herbicide, which gave a superior weed control to all other treatments, except atrazine, merits further investigation to determine whether it can be used in maiden strawberries at doses below 1.0 lb/ac without the protection of a charcoal root dip and still provide adequate weed control.

A direct comparison between cultivars in these experiments is not possible because they constituted separate experiments. There was a suggestion from plant counts that Templar was more sensitive than Cambridge Vigour to all the herbicide treatments except EPTC. This observation is supported by crop yields which, however, must be treated with even greater caution due to the generally lower yield of Templar as shown by the unsprayed control.

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COMPARISON OF HERBICIDES ON YIELDS OF ONE-YEAR OLD STRAWBERRY PLANTS

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Summary Yield data of five commercial strawberry varieties grown for annual cropping showed very few significant differences when post-planting, and/or spring, applications of lenacil were compared with low doses of simazine after planting, and simazine with spring applied lenacil. Post-planting lenacil gave a markedly better control of *Sagina procumbens* than simazine, but insufficient *Polygonum aviculare* was present for comparison of two rates of spring applied lenacil in the control of this weed.

INTRODUCTION

The production of early, good quality strawberries from unprotected plants can be achieved by annual cropping, replanting runners each August. Good weed control after planting is difficult as germination of weed seeds is rapid at this time, particularly in the warm soil and where irrigation has been applied. The use of simazine immediately, or a short time, after planting can give good weed control on some soils, but rates need careful adjustment to avoid plant damage; chloroxuron, although safer, does not control all weeds. (Hughes and Ivens 1966, Hughes 1968). Although charcoal root dipping renders the use of simazine safer it is messy to use and adds to production costs. In several herbicide experiments at Efford *op. cit.* spring germinating *Polygonum aviculare* (knotgrass) was not controlled by simazine and/or chloroxuron and necessitated spring cultivations.

Tyson (1966) and Ivens and Clay (1966) reported promising control of *Polygonum aviculare* using lenacil on strawberries and the present paper reports yield data for five strawberry varieties using this herbicide and simazine, with particular reference to quality (size) of fruit and time of ripening.

METHOD AND MATERIALS

The experimental site consisted of one-third acre in a one-year ley, ploughed during early July with addition of NPK fertilizers. The soil was Efford Type I, a very fine sandy silty loam. The design was of five randomised blocks each containing four herbicide treatment plots with a double control of the standard treatment of simazine after planting with spring cultivations if necessary. The varieties were arranged systematically. The herbicide treatment plots were separated by single guard rows and cross paths. Each recorded plot per variety consisted of 30 plants 1 ft apart in two rows at 2½ ft apart.

Five varieties were used, Cambridge Favourite, Cambridge Prizewinner, Cambridge Rival, Cambridge Vigour and Redgauntlet and runners were produced at Efford from SS mother plants. The runners were machine planted on 17 August 1966.

After planting $\frac{1}{2}$ in. irrigation water was applied as the weather was very hot. Unfortunately weeds germinated immediately after the irrigation, particularly Stellaria media (chickweed), and it was considered not possible to apply the herbicide treatments until a further cultivation with hand hoeing of the rows gave reasonably clean soil conditions.

The herbicide treatments were thus applied on 9 September, 23 days after planting and not immediately after planting as had been planned. All treatments were applied in 50 gal/ac using a hand propelled, power sprayer with 9 ft booms. The plants grew satisfactorily. Routine control measures were taken for pest and disease control.

Treatments

1. Simazine 0.38 lb a.i./ac 9 September 1966 (control)
2. Lenacil 1.25 lb a.i./ac 9 September 1966
3. Lenacil 1.25 lb a.i./ac 9 September 1966 and repeated 13 March 1967
4. Simazine 0.38 lb a.i./ac 9 September 1966 and lenacil 1.25 lb a.i./ac 13 March 1967
5. Simazine 0.38 lb a.i./ac 9 September and lenacil 2 lb a.i./ac 13 March 1967

RESULTS

Weed Control

Because of the wet weather and inadequate cultivations prior to the herbicide applications, some large plants of Stellaria media occurred throughout the experiment. These were removed by hand from the rows, and controlled by directed sprays of paraquat in the alleys, during October. There was no difference in the occurrence of these vegetatively propagated plans on plots receiving either simazine or lenacil.

Thereafter the experiment was virtually weedfree except for Sagina procumbens (pearlwort) which germinated extensively during the autumn and early spring. During early March a few germinating seedlings of Polygonum aviculare were noted, together with grass seedlings mainly Poa annua (annual meadow grass), Stellaria media, Senecio vulgaris (groundsel), Matricaria sp. (mayweed), Spergula arvensis (spurrey), and Capsella bursa-pastoris (shepherd's purse). When the lenacil was applied on 13 March to moist soil all these weeds, except pearlwort, were in the cotyledon stage.

A weed assessment was made on 10 May 1967. This showed that treatments 2 to 5, which had received lenacil either in the autumn or spring, had considerably less Sagina procumbens than treatment 1 where simazine only had been applied. All plots that had received lenacil on 13 March had less weed seedlings than plots that had only been treated with either simazine or lenacil in the autumn. There was no difference in weed control from the higher and lower rates of March applied lenacil.

The amount of weeds was small - compared with commercial conditions - and it was particularly unfortunate that a good germination of Polygonum aviculare did not occur on this site. It was not necessary to cultivate treatment 1 in the spring. All the weeds were lightly scraped off all plots prior to strawing in mid-May.

Plant Growth

Strawberry plant growth appeared similar per variety, throughout the experiment. Redgauntlet showed a pale overall chlorisis on the over wintering leaves on all plots, so this could not specifically be related to simazine or lenacil. The plants grew well in the spring and the chlorosis was soon not noticeable. No other chlorosis or damage was noticed on any other variety.

Crop

The plants were picked from 14 June until 7 July 1967. All fruit was graded as picked into large berries (<40/lb), medium berries (40-64/lb), or jam (>64/lb and mis-shapen fruit) and waste. Yield data per variety are presented in Table 1. Detailed data (not presented) show that treatments had no significant effects ($p<0.01$) on the time of ripening of marketable fruit of any variety except Cambridge Favourite. With this variety treatments 3 and 4 significantly delayed ripening.

Table 1

Marketable Yield (cwt/ac). Plants 17,424/ac

Treatment Variety	1	2	3	4	5
Cambridge Favourite	147	159	164	168*	175**
Cambridge Prizewinner	77.5	75.3	90.3	89.7	87.6
Cambridge Rival	101	119	116	116	121*
Cambridge Vigour	97.5	100	93.2	98.1	103
Redgauntlet	131	138	131	143	131

S.E. for horizontal comparisons between treatments 2 to 5 $\pm$ 7.46
**Significantly different from treatment 1 at $p<0.01$
* Significantly different from treatment 1 at $p<0.05$

Although there were some significant effects of herbicide treatments on the size of berries, amount of malformed and waste fruit these effects were not marked within each variety, nor consistent for all varieties and the data is therefore not presented.

DISCUSSION

The marketable crops were satisfactory from these varieties at this planting distance. This experiment confirmed that on five commercial strawberry varieties, grown for annual cropping on a fine sandy silty soil, lenacil applied within three weeks of planting and again in the spring gave comparable plant growth and crop as simazine also applied three weeks after planting. Previous experiments had shown this simazine treatment on this soil was comparable with cultivations. Also that lenacil could safely be used in the spring following simazine after planting. Lenacil three weeks after planting, on this relatively weedfree site, gave adequate weed control right up to strawing and comparable with simazine applied at the same time. Spring applied lenacil gave good control of spring germinating weeds, although the efficiency of two rates against *Polygonum aviculare* could not be adequately tested in this experiment. Lenacil gave a much better control of over-wintering *Sagina procumbens* than simazine.

In this experiment there were no differences in the control of spring germinating weeds between lenacil at 1.25 lb a.i./ac and 2 lb a.i./ac applied in early March.

The practical problems of applying herbicides immediately after planting strawberry runners in August were clearly demonstrated in this experiment. Irrigation, often essential to secure good recovery and growth of runner plants transplanted during hot dry periods, makes it difficult to use herbicide spray equipment immediately and within a few days rapid germination and growth of weeds, particularly *Stellaria media*, render herbicide weed control doubtful because of the size of weed seedlings present when spraying. Thus careful pre-planting soil preparations and the production of a stale seedbed, possibly by a pre-planting application of paraquat, might give more margin of time before post-planting herbicides have to be applied. It might also be possible to apply part only of the necessary irrigation, during dry conditions, and then the herbicide treatment and then to finish the irrigation application thus allowing for activation of the herbicide under very suitable conditions and at a time when weed germination and growth is at a maximum.

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POT EXPERIMENTS ON THE SUSCEPTIBILITY OF STRAWBERRIES TO SIMAZINE

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Summary Strawberry runners attached to mother plants were rooted into pots of soil treated with simazine at 1, 2 and 4 lb/ac. With July and August treatments leaf injury occurred within a month of treatment. Symptoms appeared more rapidly and were more severe where the herbicide had been incorporated in the soil before planting than where it was sprayed on the soil surface. Runners treated in September were not damaged until the following spring; the injury then occurred mainly with the soil surface treatments.

Cold stored runners and growing plants were transplanted at intervals through the growing season into pots of soil in which simazine had been incorporated. The effect of different rates of simazine on the cold stored runners did not alter greatly with successive planting dates, although symptoms were slower to develop with March and September plantings. The tolerance of the growing transplants to simazine increased at successive planting dates. Injury symptoms developed more rapidly on small plants than on large plants.

The mode of action of activated charcoal in preventing simazine injury was investigated with strawberry plants grown on a capillary bench in the glasshouse. There was no downward movement of charcoal on roots growing through a charcoal layer; charcoal was carried upwards along the root surfaces for 2 - 3 mm. by water movement.

INTRODUCTION

Since the introduction of simazine for weed control in fruit crops the susceptibility of strawberries to the herbicide has been a subject of major interest. Early research showed that the herbicide could be used on established plants in British conditions at rates up to 2 lb/ac if applied between harvest (June/July) and mid-winter (Ivens, 1962a; Robinson, 1962). Applications of 1 lb/ac, however, in the spring to established beds often caused severe leaf injury 1 to 2 months after treatment with consequent reduction in fruit yield. The incidence of injury in spring appeared to be related to climatic and soil conditions. Damage was more severe when heavy rain followed application (Ivens, 1962a) or when plants were growing in soils low in organic matter (van Staalduine, 1960). In some areas however applications in spring have not caused injury and the treatment is recommended on established beds in Scotland (Turner, 1967).

A second situation where simazine has caused damage is on newly planted beds. Rates of 1 lb/ac can cause damage if applied during the summer within a month of planting (Hughes and Ivens, 1965). It has been suggested that the reason for damage in this situation is the same as with the spring injury, uptake of simazine exceeding detoxification in the leaves thus causing damage (Ivens, 1962b). Injury to newly planted strawberries does not occur when the roots of the plants have been dipped in steam activated charcoal before planting (Robinson, 1965) although the degree of protection has been found to vary with the type of charcoal used, the crop variety and the soil type (Allott and Hay, 1966; Hughes, 1966). Where an activated charcoal dip has been used strawberries have been undamaged by rates of simazine up to 10 lb/ac applied 2 to 3 weeks after planting (Allott and Hay, 1966) which suggests

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that the charcoal must have an effect on uptake over a wider soil zone than that of the original dipped roots. A second situation where simazine does not injure young strawberry plants is the successful use of the herbicide in strawberry runner beds, where doses of 1 lb/ac applied in June cause no injury or growth reduction to mother plants or runners rooting into the treated soil (Holloway, 1962; Fryer and Evans, 1968).

In the experiments described in this paper an attempt has been made to elucidate more exactly the influence of the growth phase of the plants when treated on their susceptibility to simazine and the mode of action of charcoal in preventing injury from high doses of simazine.

METHODS, MATERIALS AND RESULTS

The experiments were all carried out using a sandy loam soil with the following analysis: coarse sand 33%, fine sand 43%, silt 11%, clay 13%, organic matter 3.1% and pH 7.7. Simazine was applied to pots of soil using a pot sprayer giving a spray volume of 29 gal/ac. A 50% w/w wettable powder formulation of simazine was used throughout; where the herbicide was incorporated 1 lb/ac simazine is taken as equivalent to 0.8 ppmw (1 lb/ac incorporated in a 4 in. layer of soil). Simazine was incorporated by passing sprayed soil through a large funnel three times. Strawberry plants (var. Cambridge Favourite) were used for all the experiments; the plants received routine pesticide applications after potting up.

Assessments of leaf injury (chlorosis and necrosis) were made at intervals in all the experiments. The plants were scored on the basis of visual symptoms on a 0 to 5 scale classified as follows:-

0 - no injury
1 - very slight injury; occasional necrotic patches on leaves
2 - slight injury; up to 10% foliage necrotic
3 - moderate injury; 40% foliage necrotic
4 - severe injury; over 80% foliage necrotic
5 - plant dead

Experiment 1. <u>The susceptibility of attached runners rooted at different times into simazine treated soil</u>

First order runners from 3 year old plants in handweeded beds were pegged onto the surface of 5 in. diameter plastic pots of soil in the field. The runners were used when the roots were just becoming visible and there were two to four leaves present. Only one runner per mother plant was used and the stolons were not severed. Simazine had been applied to the soil surface of the pots at 0, 1, 2 and 4 lb/ac and left on the soil surface or incorporated into the soil. There were four replicates of each treatment. These treatments were repeated at three dates - July 21st, August 18th and September 21st, 1964. The pots of soil were watered after setting out and later when necessary. To test whether injury occurring in the spring resulted from simazine retained in the plant or in the soil, the plants from two replicates were severed in the winter from the mother plants and repotted into untreated soil after washing off the original soil off the roots. The results of the experiment are presented in Table 1.

With the two earlier treatment dates leaf damage was seen a month after pegging down by which time the lateral root system was well developed. Symptoms appeared earlier and were more severe with the incorporated treatments. No injury symptoms developed in 1964 from plants in the last treatment date, although the plants had well developed root systems. In the following spring, no new leaf injury was seen in plants treated in July, the damage score recorded in Table 1 being an average of dead and undamaged plants. With the second date, only surface treatment with simazine at 1 and 2 lb/ac produced appreciable injury. With September treatments damage occurred from 2 and 4 lb/ac simazine; surface treatments again gave more injury. No injury symptoms were seen on those plants repotted into untreated soil during the winter.

Table 1.

The degree of leaf injury to strawberry runners rooted into simazine treated soil

Scores of degree of leaf injury

Treatment		Assessment date		11.11.64			25.5.65*	
		Planting date	21.7.64	18.8.64	21.9.64	21.7.64	18.8.64	21.9.64
Simazine	1 lb/ac	Surface	0	0	0	0	1.0	0
		Incorp.	0.5	1.1	0	0	0	0
	2 lb/ac	Surface	3.7	1.0	0	2.5	3.0	3.5
		Incorp.	3.9	3.7	0	0	5.0	1.2
	4 lb/ac	Surface	4.9	2.5	0	5.0	5.0	4.2
		Incorp.	4.9	4.7	0	5.0	5.0	4.0
Control	Untreated		0	0	0	0	0	0

* Average of only two plants in each treatment

Experiment 2. The effect of transplanting strawberries at different growth stages into simazine treated soil at different times through the growing season

Strawberry plants were lifted from a runner bed at Begbroke Hill on 5th March 1965 and either potted up in soil in 5 in. diameter plastic pots or put into a cold store maintained at 28 to 30°F. The pot plants were set out on a pot standing area and received additions of a propietary liquid fertilizer at intervals. Flower trusses and runners were removed when produced. Soil-free cold stored or growing plants were then potted up at intervals of approximately 6 weeks from March to September in 8½ in. plastic pots which contained soil in which a range of doses of simazine had been incorporated. The initial fresh weight, leaf number, number of main roots, and, for all except the first planting date, the root volumes were determined for each plant and the plants assigned to the six blocks in the experiment on a fresh weight basis. Simazine doses of 0, ½, 1, 1½, 2 and 2½ lb/ac were applied. The plants were grown on out of doors on the pot standing area and were deblossomed and derunnered when necessary. The degree of leaf injury was assessed at intervals. The final shoot weight was determined on 2nd and 3rd June, 1966.

The effect of certain of the treatments on foliage at 1 and 3 months after treatment is shown in Table 2 together with the number of plants surviving and the fresh weight of plants when harvested.

With the first date of planting the rate of onset of injury symptoms was the slowest of any planting date but the effects were eventually almost the most severe. All the plants were killed by the 1½ lb/ac treatment and moderate injury and growth reduction resulted from the ½ lb/ac treatment. Later plantings of cold stored runners developed injury symptoms more quickly than did the first planting and this was particularly true of the April and late June treatments but the eventual degree of effect was comparable. The September treatments developed injury symptoms slowly but all the plants, including untreated controls died during the following winter. The growing transplants were most susceptible to simazine at the mid-April date when the 1½ lb/ac simazine resulted in the death of all the plants. With later plantings, damage was progressively less and the September plantings showed no injury even at the highest dose. There were no leaf injury effects occurring the following year. The other doses of simazine not shown in the table were intermediate in their effects.

Table 2.

Leaf injury, mortality, and fresh weight of growing plants and cold stored runners treated with different rates of simazine

Planting date	Simazine dose (lb/ac)	Leaf injury assessed after 1 month		3 months		No. of plants killed[x] (on 3.6.66)		Final mean wt. surviving plants (g)	
		G*	S*	G	S	G	S	G	S
9.3.65	0	0		0		0		50.1	
	½	0		3.4		1		40.2	
	1½	0.3		5.0		6		-	
	2½	0.5		5.0		6		-	
20.4.65	0	0	0	0	0	0	0	54.0	48.2
	½	3.2	1.3	1.7	2.5	0	1	43.4	43.3
	1½	4.2	2.3	5.0	5.0	6	6	-	-
	2½	4.7	2.3	5.0	5.0	6	6	-	-
15.6.65	0	0	0	0	0	0	0	37.4	33.1
	½	0	0	0	0.2	0	1	36.7	32.5
	1½	1.0	2.8	2.8	5.0	2	6	21.1	-
	2½	2.1	2.9	4.2	5.0	5	6	13.9	-
30.7.65	0	0	0	0	0	0	0	41.2	23.1
	½	0	3.2	0	1.7	0	3	50.1	7.5
	1½	2.2	4.8	2.2	5.0	0	6	21.1	-
	2½	3.6	5.0	1.4	5.0	1	6	6.1	-
14.9.65	0	0	0	+	+	0	6	31.2	-
	½	0	0.2	+	+	0	6	38.3	-
	1½	0	2.6	+	+	0	6	35.2	-
	2½	0	4.2	+	+	0	6	38.7	-

* Type of plant material, G = growing plants, S = cold stored runners
x Number killed out of six
\+ No record taken

Data on the influence of initial plant size on simazine injury is presented in Table 3. The rate of onset of injury symptoms was definitely slower with larger plants but the final effect of each rate of chemical was little different. The difference in rate of development of injury symptoms was less clearly marked with the later planting dates.

Experiment 3. The mode of action of charcoal root dips in protecting strawberries from simazine injury

The mode of action of charcoal in giving protection from injury from high doses of simazine applied immediately after planting was investigated. The experiment was carried out in the glasshouse using small strawberry runners taken from a runner bed at Begbroke Hill the roots having been washed to remove soil and trimmed to facilitate planting. The runners were planted in untreated soil in open ended containers placed on top of pots of soil treated with different rates of simazine. A thin layer of steam activated charcoal (Harrison, Clark's wood charcoal, grade A.C.1.) was placed at a set distance from the bottom of the cylinder and soil placed on top of this to give a total depth of 1.25 in. The experimental system is illustrated in Figure 1.

Table 3.

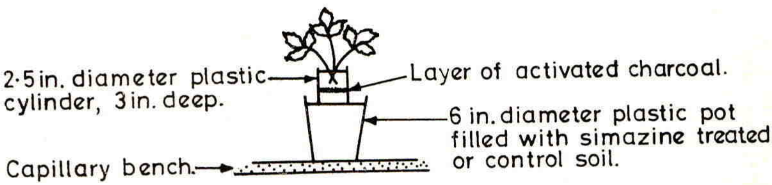
The effect of initial plant size on the degree of simazine injury from one treatment date and the total number of plants killed for all treatments

Means of four rates of simazine (1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$ lb/ac)

Size group	1	2	3	4	5	6
Fresh wt. at planting (g) (20.4.65)	12.0	13.9	17.0	19.5	22.4	29.8
Damage score on 10.5.65 (score 0-5)	3.6	3.3	2.9	2.9	2.1	1.7
Total no. of plants killed in all simazine treatments*	24	22	20	24	20	22

* Number killed out of a possible 45

Fig.1. Growing system used for the test of charcoal action



A measured volume of charcoal was placed at 0, $\frac{1}{2}$ or 1 in. from the treated soil surface to give a layer 0.1 in. thick; with one treatment, no charcoal was added. The pots of treated soil contained simazine at 0, 1, 2 and 4 lb/ac. There were four replicates of each treatment. The pots were planted on 13th March, 1967 and were placed on a capillary bench; assessments were made of degree of leaf injury at intervals and final shoot weight was recorded on 2nd May 1967. The results of these assessments are presented in Table 4.

The results show the effect of the charcoal in delaying leaf injury and reducing the final degree of damage to the plants. With each of the four rates of simazine used the closer the charcoal layer was to the treated soil, the slower were the injury symptoms to develop, the less severe were the symptoms and the smaller was the reduction in shoot weight. The only exception to this trend was the effect of 4 lb/ac simazine where the charcoal was immediately over the treated soil.

Table 4.

The effect of distance of a charcoal layer above simazine treated soil on development of leaf injury and on final shoot weight of strawberries planted above this layer

Charcoal treatment	Simazine dose (lb/ac)	Mean leaf injury (assessed on scale 0-5)						Number of living plants (out of 4)	Mean fresh wt. snoots (g)
		Weeks after planting							
		1	2	3	4	5	6		
A	0	0	0	0	0	0	0	4	10.3
	½	0	0.5	1.6	1.9	2.4	2.4	4	5.4
	1	0.2	3.1	4.5	4.9	5.0	5.0	0	0
	2	0.8	3.8	4.4	4.7	5.0	5.0	0	0
	4	1.8	4.5	5.0	5.0	5.0	5.0	0	0
B	0	0	0	0	0	0	0	4	9.2
	½	0	0	0	0	0	0	4	9.3
	1	0	0	0	0	0	0	4	11.4
	2	0	0	1.4	2.0	2.0	2.2	4	8.6
	4	0	0.2	2.7	3.9	4.7	5.0	0	0
C	0	0	0	0	0	0	0	4	12.4
	½	0	0	0	0	0	0	4	10.8
	1	0	0	0	0	0	0	4	11.7
	2	0	0	0.1	0.4	0.5	0.5	4	10.9
	4	0	0.2	0.6	1.9	3.4	3.7	3	6.3
D	0	0	0	0	0	0	0	4	13.7
	½	0	0	0	0	0	0	4	16.1
	1	0	0	0	0	0	0	3	13.7
	2	0	0	0	0	0	0	4	12.0
	4	0	0	2.4	3.4	3.7	4.0	3	4.2

Charcoal treatments

A - No charcoal added
B - Charcoal 1 in. from treated soil
C - " ½ in. " " "
D - " overlying " "

DISCUSSION

Leaf injury from applications of simazine has been seen to occur in a variety of circumstances. The suggestion has been made that injury occurs only when the detoxification rate in the leaves falls below the rate of uptake through the roots (Ivens, 1962b). Strawberry plants must possess a certain capacity to breakdown simazine since in these experiments actively growing transplants usually showed no symptoms when planted up in the summer in soil treated with simazine at ½ lb/ac.

It follows therefore that the herbicide may be expected to be safe to use when the amount entering the plant is low e.g. from autumn to early spring, on runner beds and with charcoal treated plants. Conversely it will only cause injury when a high proportion of the absorbing roots are near the surface as with newly planted runners or in established beds in spring. The results of the experiments above are in line with this hypothesis.

Damage to newly rooting runners only occurs when the fibrous lateral roots are well developed and are growing in a sufficient concentration of herbicide; runners rooting in August through the recommended dose of 1 lb/ac sprayed on the soil surface (Fryer and Evans, 1968) were not damaged by the treatment. Injury was not seen on September treated runners when growth was slower although the fibrous root system was well developed. The occurrence of injury symptoms in the spring following treatment in August and September was shown to result from simazine remaining overwinter in the soil, the surface treatments causing more injury than the incorporated treatments. This corresponds to the frequent observation of leaf necrosis in spring on shallowly rooted runners in beds following the use of residual herbicides (Sutherland, 1960).

The experiment testing the effect of simazine on strawberries planted at different times of year confirms results from preliminary work on the influence of growth stage of transplants on susceptibility (Ivens, 1964). The results indicate the toxicity of low doses of simazine to newly planted runners during the growing season and the reduction in the rate of development of injury symptoms in March and September when growth is slow. A similar difference in response due to time of planting has been demonstrated in field conditions; treatment with 1 lb/ac simazine 5 days after planting in September caused no foliar damage whereas the same treatment applied 7 days after planting in August caused leaf injury in September (Hughes and Ivens, 1965). The slower resumption of shoot growth in northern areas may be the reason simazine can be used safely in spring in Scotland.

The slightly increased susceptibility of the cold stored runners when planted in summer and the death of all the September planted runners the following winter may have been due to a non-apparent deterioration in the condition of the plants during storage. In other experiments at Begbroke Hill stored runners have been found to be less susceptible to leaf injury when planted in mid-summer compared with spring planting. The final results in this trial indicated little difference due to the time of year when the chemical was applied to newly planted stock.

There was a steady decrease in the susceptibility of actively growing plants to simazine with succeeding planting dates, apart from the slight increase in toxicity from the July treatments. This decreased effect of simazine might result from the increased capacity of the larger plants to detoxify the simazine. Comparison with the damage caused to newly planted runners from the same treatment date indicates that toxicity was not reduced by accelerated breakdown of simazine in summer conditions.

Information was obtained on the effect of initial plant size on susceptibility. Differences were clearer with the spring treatments where there was a definite increase in the rate of appearance of injury symptoms with smaller plants (Table 3). The data on the total number of plants killed, however, suggests that in pots the difference in susceptibility is only temporary. In field conditions downward growth of roots away from the treated layer could mean that this initial difference in susceptibility is maintained. This has been indicated in a field trial with the variety Redgauntlet (Hughes, 1966).

One factor considered of importance in disposing strawberries to injury from simazine in spring is the high root : shoot ratio at that time of year (Ivens, 1962). A study of the effects of simazine in relation to the root : shoot ratio of the plants used in this experiment showed a consistent trend of increased injury with increase in root : shoot ratio for both stored and growing transplants but the differences were not large.

The experiment on the positioning of the charcoal layer illustrates the effectiveness of the material as an adsorbent. The fact that damage took longer to develop where the charcoal was nearer the treated soil might suggest the adsorbent was being moved on the roots into the treated soil - one possible explanation for the protection of plants from injury from high doses of simazine. Microscopic examination of the roots however showed that the only movement of charcoal was upwards along the root surface for a distance of 2 to 3 mm, presumably resulting from the upward water movement in the system. When test plants (turnip) were grown in soil taken from above the simazine treated zone but below the charcoal layer, they were killed off indicating the presence of simazine residues greater than 1 oz/ac resulting from upward movement from the treated zone. Test plants grown in soil taken from above the charcoal layer, however, were not injured at all. The reasons for the earlier damage where the charcoal layer was at a distance would seem to be that the herbicide had moved upwards and was therefore taken up earlier by the roots. The movement of charcoal for a short distance upwards along the root surfaces suggests that where runners with roots dipped in charcoal are planted in the field, downward water movement, particularly in heavy rain, could carry the charcoal along the growing roots away from the original zone, thus increasing protection from simazine injury.

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A COMPARISON OF CULTIVATION AND NON-CULTIVATION IN THREE STRAWBERRY CULTIVARS

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Summary In three strawberry cultivars no differences in crop yield were recorded on cultivated and non-cultivated plots over a three year period. Mulches of straw and farm yard manure had little effect on yield under both systems of soil management.

The compact soil surface of non-cultivated plots provided very suitable conditions for fruit harvesting and the passage of machinery, and facilitated weed control after the first season. In view of these advantages it is concluded that non-cultivation is a better method of soil management than cultivation on many soil types in spite of the absence of any direct beneficial effect on the growth and yield of strawberries.

INTRODUCTION

In a previous experiment on methods of soil management in strawberries, no differences were recorded in crop yields on cultivated and non-cultivated plots (Robinson, 1962). As weed control was more effective and less expensive in herbicide-treated plots it was concluded that a system of management, based on herbicides without any soil cultivation was a promising alternative to conventional cultivation in strawberries. These initial results with non-cultivation were obtained on a fine sandy loam, using the cultivar Cambridge Vigour. A similar experiment at the Soft Fruit Research Centre, Clonroche, Co. Wexford was designed in 1964 to determine if similar results applied to other cultivars and another soil type.

METHOD AND MATERIALS

The strawberries were planted in May, 1964 on a level site following a short term ley. The soil, part of the Clonroche series, was a clay loam containing in the 0 - 6 in. layer approximately 19% coarse sand, 9% fine sand, 40% silt, 25% clay and 3.0% organic carbon.

The experiment had a split plot design with two methods of soil management (herbicides and cultivation) as main plots (each 25 yd x 2 yd) and three mulching treatments as sub-plots (8.3 yd x 2 yd). Main treatments were replicated three times in each of the three cultivars Cambridge Vigour, Senga Sengana and Gorella. Mulching treatments, consisting of straw 2 ton/ac and farmyard manure 10 ton/ac, were applied in spring 1965, 1966 and 1967 and were subsequently worked into the soil on cultivated plots. No additional mulch was used to protect the fruit from soil splashing.

The strawberries were planted 18 in. apart in rows 3 ft apart. A single row in the centre of each plot was recorded and the row on either side served as a guard row. Routine applications of fungicides, insecticides and fertilisers were made throughout the period of the experiment.

Normal cultivation was given until March, 1965 when the experimental treatments were started. From this period, weeds and runners in the cultivated plots were controlled by hand hoeing within the plant row and mechanical cultivation along the rows. Both these operations were carried out four to six times each year. Weeds were controlled on the herbicide-treated

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plots mainly by overall application of simazine. This herbicide (lb/ac) was applied in : March, 1965 (0.75); August, 1965 (1.5); January, 1966 (0.75); August, 1966 (1.5) and January, 1967 (0.75). Each year paraquat at 1 lb/ac was used as a directed inter-row spray to control runners and established weeds. In August, 1965 a small number of established weeds, mainly Lathyrus pratensis and Vicia cracca which would be difficult to control chemically were removed by hand.

Records were made of crop yield, plant vigour and weed growth. An analysis of variance was carried out on the crop yield of each cultivar separately and also on the combined data of the three cultivars. The analyses were conducted on the data in each individual year and also for 1965 + 1966 and for 1965 + 1966 + 1967.

RESULTS

The total yields of the three cultivars for each of the three seasons and for 1965 + 1966 and 1965 + 1966 + 1967 are presented in Table 1. The results for the three cultivars separately are presented in Tables 2, 3 and 4. Yields were similar on cultivated and non-cultivated plots for all cultivars and in all seasons. The "F" test for interaction and for main effects was not significant in all analyses. Cambridge Vigour considerably outyielded the other cultivars in all seasons. Senga Sengana cropped poorly due to weak plants and small berry size and mulching and management systems had least effect on this cultivar. The yield of Gorella was rather variable in the third year, due probably to root disorders which occurred in some parts of the experimental area. With cultivars Cambridge Vigour and Gorella slightly better results were obtained in the non-cultivated plots where the farmyard manure mulch was used. On cultivated plots of these cultivars slightly higher yields were given by the straw mulch and no mulch treatments.

Measurements of plant height and width showed no significant differences between cultivated and non-cultivated plots and between mulching treatments. There was no evidence of herbicide injury on any of the non-cultivated plots throughout the period of the experiment.

The results of weed counts and ratings showed that the herbicide programme was highly effective against the weeds present in the area. The two applications of simazine annually, supplemented by spot treatment with paraquat, maintained the ground in an almost weed free condition. Few weeds germinated on herbicide-treated plots after the first year and the ground remained almost weed free. The mulches of straw and farmyard manure had little effect on the herbicide treatment.

Weed control in the cultivated plots was less satisfactory being frequently hindered by wet weather. Although six hoeings and cultivations were given in 1965, four in 1966 and five in 1967 the ground was usually 50 - 75% covered with weeds before each hoeing.

Two applications of paraquat in autumn 1965 and one application in 1966 gave satisfactory control of runners in all three cultivars.

DISCUSSION

These results are in agreement with previous experience of non-cultivation in strawberries (Robinson, 1962). There was no evidence of any increase in yield or vigour where cultivation was eliminated in contrast to the results obtained with gooseberries (Allott and Robinson) and black currants. This difference in response between strawberries and bush fruits may be due to differences in rooting habits. When a system of non-cultivation is used in black currants or gooseberries these crops often produce a vigorous root system in the surface soil which is usually the richest in nutrients. Strawberry plants also produce more shallow roots if no cultivations are given (Robinson, unpublished) but do not appear to exploit the surface soil as extensively as non-cultivated black currants or gooseberries. In addition the strawberry is less responsive to soil nutrient levels than the bush fruits.

A crust formed on the surface of unmulched cultivated plots in spring, 1965 and persisted until the end of the experiment. The crust was very thin and did not appear to extend more than a few millemetres from the surface.

Although these results agree with the previous experience that non-cultivation does not result in any increase in yield of strawberries, several indirect benefits occur as a result of the compaction of the surface soil. In this experiment fewer weed seeds germinated in the non-cultivated plots than in cultivated ones in 1966 and 1967. The plot size was too small to enable the cost of the two systems to be compared but it was clear that the herbicide system was less expensive under conditions at Clonroche, particularly in the last two years. The compact, slightly moss-covered surface of unmulched non-cultivated plots helped to protect berries from soil splashing and provided cleaner working conditions for fruit pickers than did cultivated plots. The surface of the non-cultivated plots was unmarked by machinery throughout the three year period whereas the cultivated plots were badly tracked on a few occasions.

Although the straw and farmyard manure had no effect on yield, an organic mulch would be necessary where non-cultivation is adopted on a sloping site to minimise erosion. In this experiment the area was almost flat, rain penetrated easily and no erosion occurred.

Weeds in the seedling and young plant stage can significantly reduce the yield of annual vegetable crops (Bleasdale, 1959). There was no evidence of any yield reduction on cultivated plots in this experiment even though the ground was sometimes almost covered with weeds before hoeing. Presumably established strawberries are less sensitive to occasional weed competition than annual crops in the seedling and young plant stage.

More information has become available recently on the successful use of non-cultivation in strawberries on a range of different soil types (Robinson, 1967; Procter, 1968; Hughes, 1968). There may be some soils where cultivation would benefit strawberries even if weeds are absent. For example, Van Doren and Prihar (1968) report that in Ohio cultivation increases corn yields in the absence of weeds on silt loams with less than 2% organic matter. However, such soils do not appear to be common and no evidence has been found of soil types on which non-cultivation adversely effects strawberries.

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Table 1

Effect of cultural systems and mulching treatments on crop yield (cwt/ac).

Mean of 3 cultivars

Year	Soil management	Mulching treatment: No mulch	Straw	FYM	Mean	S. E.: Non-cultivation v. cultivation (df = 6)	Between mulches (df = 24)
1965	Non-cultivation	79.4	82.5	90.3	84.1		
	Cultivation	93.8	89.1	86.5	89.8	± 7.35	± 3.67
	Mean	86.8	85.8	88.4	86.9		
1966	Non-cultivation	79.3	77.2	83.2	80.0		
	Cultivation	79.2	83.3	72.1	78.2	± 3.96	± 4.40
	Mean	79.3	80.3	77.7	79.1		
1967	Non-cultivation	73.0	72.5	72.7	72.8		
	Cultivation	75.4	80.6	73.5	76.5	± 6.42	± 5.60
	Mean	74.2	76.6	73.1	74.6		
1965 + 1966	Non-cultivation	158.7	159.6	173.5	164.1		
	Cultivation	172.9	172.5	158.6	168.2	± 8.44	± 7.04
	Mean	165.8	166.1	166.3	166.1		
1965 + 1966 + 1967	Non-cultivation	231.2	232.1	246.3	236.5		
	Cultivation	248.3	252.9	232.1	244.4	± 13.3	± 12.2
	Mean	238.8	242.5	239.2	240.2		

Table 2

Effect of cultural systems and mulching treatments on crop yield (cwt/ac), of cultivar Cambridge Vigour

Year	Soil management	Mulching treatment			Mean	S. E.	
		No mulch	Straw	FYM		Non-cultivation v. cultivation (df = 2)	Between mulches (df = 8)
1965	Non-cultivation	117.8	117.4	120.3	118.5		
	Cultivation	135.4	132.1	122.1	129.9	± 7.92	± 2.59
	Mean	126.6	124.8	121.2	124.2		
1966	Non-cultivation	102.2	99.6	109.7	103.8		
	Cultivation	99.2	111.5	88.2	99.6	± 5.05	± 4.03
	Mean	100.7	105.6	99.0	101.7		
1967	Non-cultivation	115.1	118.4	109.5	114.4		
	Cultivation	117.5	120.5	108.9	115.6	± 4.78	± 6.08
	Mean	116.3	119.4	109.2	115.0		
1965 + 1966	Non-cultivation	220.0	217.0	230.0	222.3		
	Cultivation	234.6	243.7	210.3	229.5	± 3.19	± 5.69
	Mean	227.3	230.3	220.2	225.9		
1965 + 1966 + 1967	Non-cultivation	335.1	335.4	339.6	336.7		
	Cultivation	352.1	364.1	319.2	345.1	± 3.09	± 9.59
	Mean	343.6	349.7	329.4	340.9		

Table 3

Effect of cultural systems and mulching treatments on crop yield (cwt/ac), of cultivar Gorella

Year	Soil management	Mulching treatment: No mulch	Straw	FYM	Mean	S. E.: Non-cultivation v. cultivation (df = 2)	Between mulches (df = 8)
1965	Non-cultivation	59.9	73.8	81.8	71.8		
	Cultivation	77.9	77.5	65.4	73.6	± 5.91	± 3.64
	Mean	68.9	75.7	73.6	72.7		
1966	Non-cultivation	83.2	86.4	85.4	85.0		
	Cultivation	90.5	93.8	76.7	87.0	± 1.46	± 4.90
	Mean	86.8	90.1	81.0	86.0		
1967	Non-cultivation	71.5	76.8	78.6	75.6		
	Cultivation	81.4	97.4	85.0	87.9	± 8.47	± 6.70
	Mean	76.4	87.1	81.8	81.8		
1965 + 1966	Non-cultivation	143.1	160.2	167.2	156.8		
	Cultivation	168.3	171.3	142.1	160.6	± 7.14	± 7.62
	Mean	155.7	165.7	154.7	158.7		
1965 + 1966 + 1967	Non-cultivation	214.5	237.0	245.8	232.4		
	Cultivation	249.7	268.7	227.1	248.5	± 14.50	± 5.80
	Mean	232.1	252.8	236.4	240.5		

Table 4

Effect of cultural systems and mulching treatments on crop yield (cwt/ac), of cultivar Senga Sengana

Year	Soil management	Mulching treatments			Mean	S. E.	
		No mulch	Straw	FYM		Non-cultivation v. cultivation (df = 2)	Between mulches (df = 8)
1965	Non-cultivation	60.9	56.4	69.2	62.2	± 8.05	± 4.55
	Cultivation	68.3	58.0	72.4	66.2		
	Mean	64.6	57.2	70.8	64.2		
1966	Non-cultivation	52.7	45.7	54.7	51.0	± 4.41	± 4.26
	Cultivation	48.0	44.9	51.7	48.2		
	Mean	50.3	45.3	53.2	49.6		
1967	Non-cultivation	32.7	22.6	30.3	28.5	± 5.41	± 3.52
	Cultivation	27.6	24.0	26.7	26.1		
	Mean	30.1	23.3	28.5	27.3		
1965 + 1966	Non-cultivation	113.6	102.1	123.9	113.2	± 12.36	± 7.63
	Cultivation	116.3	102.9	124.0	114.4		
	Mean	114.9	102.5	124.0	113.8		
1965 + 1966+ 1967	Non-cultivation	146.2	124.7	154.2	141.7	± 17.68	± 10.26
	Cultivation	143.8	126.8	150.7	140.5		
	Mean	145.0	125.8	152.5	141.1		

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TRIALS TO INVESTIGATE THE HERBICIDAL EFFICACY OF DICHLOBENIL IN BUSH FRUIT WITH SPECIAL REFERENCE TO THE CONTROL OF AGROPYRON REPENS.

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Summary Field trials were conducted in 1966/67 using a 7.5% granular formulation of dichlobenil. The results indicate that heavy infestations of *Agropyron repens* can be controlled throughout the growing season from spring applications but that surviving rhizomes start growth again in the late summer/early autumn, the effect of dichlobenil in its second consecutive year of application being still under investigation. The results also provide information on the susceptibility to dichlobenil of a range of annual and other perennial weed spp. Blackcurrants and gooseberries displayed a wide margin of crop tolerance, there being no adverse effect on extension growth or any visible symptoms of phytotoxicity at rates of up to 30 lbs/ac.

INTRODUCTION

The results of trials on top and bush fruit with dichlobenil applied in wettable powder and granular formulations have been reported by Sandford (1962) and have shown that both blackcurrants and gooseberries were unaffected by dichlobenil at 8 lbs/ac (soil incorporated). Sandford (1964) however, has reported slight phytotoxicity on established gooseberries following field applications of up to 10 lbs/ac of the related chemical chlorthiamid, which is broken down in the soil to form dichlobenil. Such phytotoxicity, where it occurred, was more prevalent on the lighter soil types. The present series of four trials on bush fruit (1 gooseberry, 3 blackcurrant), was laid down in 1966 to investigate further the effect of dichlobenil granules on sites objectively selected because of the heavy infestation of *Agropyron repens* which was dominant on each. Although the incidence of other weeds was sporadic on some of these sites, observations on such other weeds as were present were recorded and are presented. To obtain further data on crop tolerance, a range of application rates to a maximum of 30 lbs/ac (not incorporated) was applied in both autumn and spring.

METHOD AND MATERIALS

A 7.5% granular formulation of dichlobenil was used throughout. All dosage rates are expressed as lbs. active ingredient/ac. Band application which was extended to the alley centres was made with a hand dispenser of pepper pot design at 7.5: 9.75: 12.0: 19.5: 24 and 30 lbs/ac.

To obtain more precise data on the effect of timing of application, a range of dosage rates applied in the autumn, (September, October and November) and in the spring, (February, March and April) was compared, observations also being made on other plots, where, before application, the natural growth of *Agropyron repens* was encouraged by cutting prior to the autumn flush.

Trials design comprised a randomised block, the number of replicates, 3, 4 or 5, depending on individual site size with the exception of the two highest rates, which, throughout, comprised single unreplicated but double sized plots. To cover soil and climatic variations, the sites were selected on a geographical basis, their distribution and other details being shown in Table 1.

Table 1

Trial No. and Location.	Crop	Soil	Plot Size Area	No. of bushes
1 Worcs	Gooseberry	Loamy sand	10' x 15'	3
2 Glos	Blackcurrant	Silty clay	10' x 12'	4
3 Suffolk	"	Loamy sand	8.5'x 12'	4
4 Kent	"	Light clay with flints.	9' x 27'	3

Results were assessed at the time of the September and March applications and thereafter at approximately monthly intervals using a linear scale of 0 - 10, where 0 represents bare ground and 10 by 100% weed cover. The results in Table 2 are expressed as percentage control of the original infestation. Where weeds such as Rumex and Cirsium spp were growing through a complete ground cover of Agropyron repens and/or Agrostis spp, these and other weeds were assessed separately. Crop extension growth measurements were recorded in the autumn of 1967 and in addition, visual assessments of crop appearance and vigour were noted throughout the period of the trials whenever weed assessments were made.

RESULTS

I Control of Agropyron repens.

In general, (see Table 2) the results followed closely the pattern which might be expected, namely, superior weed control with increasing dosage rate, herbicidal persistency continuing later into the year from the later applications and superior control on sites sited on the lighter soils.

Table 2

Mean percentage control of Agropyron repens obtained from spring and autumn applications

Assessed.	Applied Dose.	September	October	November	February	March	April
March	7.5	78	74	81			
	9.75	79	87	91			
	12.0	89	91	94			
April	7.5	70	70	81	80		
	9.75	70	78	80	88		
	12.0	77	87	90	91		
June	7.5	57	43	57	70	78	47
	9.75	48	57	70	82	84	70
	12.0	61	77	88	88	91	74
July	7.5	46	38	29	62	60	61
	9.75	45	41	53	72	77	77
	12.0	55	60	64	72	83	88
August	7.5	11	11	7	26	51	63
	9.75	16	22	16	44	57	87
	12.0	57	47	44	54	63	91
September	7.5	4	5	2	15	36	44
	9.75	7	13	6	20	37	52
	12.0	32	28	30	29	43	72

a) **Effect of application rate.**

The results indicate that rate of application influences control in two ways. Firstly, the degree of initial control - i.e. the maximum level of control obtained prior to any regrowth, and secondly, the duration of suppression of the surviving rhizomes (residual action).

At 7.5 lbs, initial control varied between 63% (April application) and 81% (November application). At 9.75 lbs, the initial control varied between 79% (September application) and 91% (November application). At 12.0 lbs, initial control was between 89% (September application) and 94% (November application). Spring treatments were intermediate at the last two rates. Thus, with every 2.25 lbs increase in application rate, initial control was improved by approximately 10%.

Residual activity may be defined as that period which elapses between application to when the level of control falls below an arbiterally acceptable standard, which in this case is taken to be 60%. At 7.5 lbs, the autumn applications provided a residual activity of 8 months (September application); $6\frac{1}{2}$ months (October application) and 6 months (November application) - an overall mean of 6.8 months, the corresponding residual activity for the spring treatments being 4 months (February application) and 3 months for the March and April applications.

At 9.75 lbs, the residual activity of the autumn applications was increased by approximately a fortnight and by up to a month with the spring applications. A similar improvement was obtained by increasing the application rate to 12.0 lbs.

Although data from the 19.5 lbs rate is not presented, the results showed that despite a very slight increase in the cover of Agropyron repens, which occurred between June and August on the autumn treated plots, effective control was obtained until the autumn regardless of application date.

b) Effect of timing of application.

Timing of application influenced to only a small extent the degree of initial control, which at 7.5 lbs achieved maxima of 78% (September application); 74% (October application) and 81% (November application) in comparison with 80% (February application) and 78% (March application). Likewise, at 12.0 lbs, the maxima varied between 89% (September application) and 94% (November application), a maximum control of 91% being obtained from the October, February, March and April applications. The results from 9.75 lbs were intermediate.

Residual action however was greatly influenced by the major differences in timing - i.e. autumn as opposed to spring, but to a far lesser extent by minor differences between the two main periods - i.e. September compared with October or November, or February compared with March or April. Broadly speaking, autumn applications had a residual activity approximately twice that of the spring applications, probably due to the cooler and wetter conditions during the autumn which resulted in less volatilization of dichlobenil when soil and air temperatures were low and by the better natural incorporation provided by winter rains. A comparison of individual applications, made either in the autumn or spring shows that the later the application, the longer into the following season the residual action persisted, and likewise, the overall effect of the spring applications lasted later in the season than the overall effect of the autumn applications.

In terms of actual couch control, there is little advantage to be derived from the longer residual action provided by application in the autumn unless the ensuing control persists well into the following July when there is insufficient time for regrowth to become too well established or troublesome to the crop. The results of these trials indicate that a rate of 12.0 lbs or more is necessary to obtain this length of action from an autumn application. (The advantages of autumn application in terms of improved crop vigour are discussed later).

Although at 7.5 lbs, adequate couch control during July was not achieved by the autumn applications, with applications made in February and March an acceptable level of control was realised until the beginning of July, and to the beginning of August when applied in April, whilst at 9.75 lbs, the February applications lasted well into July and to the beginning of August from both March and April applications. A residual action which persisted until July was obtained at 12.0 lbs from the autumn applications, and when applied in the spring, until mid-August from the March application and until the beginning of October from application in April.

c) Effect of cutting prior to treatment.

The control of Agropyron repens achieved with some translocated herbicides is improved if application is made to a vigorously growing stand. Growth on certain plots was cut off in August in an effort to stimulate the natural vigour of the autumn flush prior to application. The data (not presented) showed that the effect of cutting resulted in a marginal improvement in initial control of approximately 5%. Cutting however resulted in reduced persistence such that by the beginning of July, the level of control on the uncut plots had exceeded that of the cut plots by approximately 9%.

d) Effect of soil type.

The geographical distribution of the trials included two light sands of similar analysis, a heavy silty clay and a somewhat lighter clay with flints. The results which are in accordance with Sandford's findings showed superior weed control on the lighter soil types.

II Control of other weeds.

Weed control data in respect of some of the other important perennial weeds which were present on the four sites is shown in Table 3 and are expressed as the mean of the three autumn/spring applications as appropriate.

Table 3

Percentage weed control (Mean of autumn/spring applications).

Assessed	June			July			August			September		
Dose	7.5	9.75	12.0	7.5	9.75	12.0	7.5	9.75	12.0	7.5	9.75	12.0
Agrostis spp	54	75	91	62	73	91	58	92	94	62	87	96
Rumex spp	88	100	99	92	99	100	93	95	92	79	79	80
Cirsium arvense	100	92	100	81	82	79	62	67	80	69	70	78
Ranunculus repens												
autumn	0	18	11	0	8	25	0	8	36	0	8	36
spring	19	39	36	25	30	72	25	29	45	28	31	47
Convolvulus arvensis												
autumn	13	34	47	0	0	13	0	0	0			
spring	71	82	88	13	46	25	0	15	0			

Data from the autumn applications has not been presented in respect of Agrostis, Rumex and Cirsium spp, as timing of application made little difference to the results obtained. Timing of application however resulted in a marked difference in the control of Ranunculus repens and Convolvulus arvensis. It will be noted that Agrostis, Rumex and Cirsium spp are all susceptible at the lowest rate of application (7.5 lbs) and were controlled throughout the season. The response at 7.5 lbs of other perennial weeds which were more sporadic in their occurrence was as under:-

Susceptible.
Artemisia vulgaris, Achillea millefolium, Cerastium vulgatum, Equisetum arvense, Matricaria spp, Tussilago farfara.

Moderately susceptible.
Cardaria draba, Urtica dioica, Trifolium repens.

Moderately resistant.
Solanum dulcamara.

Resistant.
Heracleum sphondylium, Rubus spp, Scabiosa columbaria.

The following annual weeds observed in the trials were very susceptible to dichlobenil at 7.5 lbs with the exception of Galium aparine and Geranium dissectum which were classed as moderately susceptible:-

Capsella bursa-pastoris, Cerastium vulgatum, Chenopodium album, Mercurialis annua, Papaver spp, Polygonum aviculare, Poa annua, Senecio vulgaris, Sinapis arvensis, Sisymbium officinale, Sonchus spp, Stellaria media.

III Crop tolerance.

In the absence of yield data, extension growth measurements were recorded from autumn and spring treatments as an alternative indicator of crop phytotoxicity. Visual assessments of crop appearance and vigour were noted throughout the period of the trials, there being no adverse visual symptoms resulting from any of the applications either to gooseberries or to blackcurrants. Although gooseberry and blackcurrant extension growth data in respect of the 24 and 30 lb treatments is presented, it should be noted that owing to lack of replication of these very high rate plots, the data could not be included in the analysis of results and levels of significance are thus only quoted where appropriate at 9.75 and 19.5 lbs. Measurements were made of the number of new shoots which were produced during the course of the season, their aggregate length (total new growth) and of the mean shoot length.

Gooseberries.

Table 4

Extension growth data - gooseberries inch/bush.

Applied	October			November			March			April		
Measurements	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
Control	76.2	16	4.6	76.2	16	4.6	76.2	16	4.6	76.2	16	4.6
9.75				293.0 (ac)	47 (ac)	6.2 (a)	94.8	25	3.7	65.6	17	3.6
19.5				255.3 (ac)	48 (ac)	5.5 (b)	120.5	30 (ae)	3.8	59.4	15	3.7
24.0	493.7	85	5.7				126.0	32	3.8			
30.0	260.3	48	5.6				117.0	35	3.3			

M1 = Total new growth
M2 = No. of shoots
M3 = Mean of shoot length.

a Sig.-greater than control P= 0.01
b " " " " P=<0.05
c " " " March and April P= 0.01
e " " " April P= 0.01

The results show:-

a) Application in November resulted in significant increases over the control in total extension growth, the number of new shoots and in their mean length.

b) November applications resulted in significant increases over the March and April treatments in total extension growth and in the number of new shoots produced.

c) March applied treatments produced increases over the control in total extension growth and in the number of new shoots and a small reduction in their mean length, these differences not achieving statistical significance with the exception of the

19.5 lb treatment, which, in respect of shoot numbers, was significantly greater than the control.

d) Whilst there was little difference in the number of new shoots resulting from April application compared with the control, there was a reduction in total extension growth and mean shoot length, these differences however not being significant.

e) The largest increase in growth occurred on the 24.0 lb treatment in both autumn and spring, thus indicating the very high tolerance of gooseberries to dichlobenil.

Blackcurrants.

Table 5

Extension growth data - blackcurrants inch/bush.

Applied	October			November			March			April		
Measurements	M1	M2	M3	M1	M2	M3	M1	M2	M3	M1	M2	M3
Control	297.9	46	6.1	297.9	46	6.1	297.9	46	6.1	297.9	46	6.1
9.75				627.4 (b)	68	9.4 (af)	426.9	50	8.4 (b)	496.9	63	7.1
19.5				803.0 (ad)	81	10.2 (af)	454.0	55	8.1	418.0	56	7.5
24.0	506.1	52	10.6				375.4	52	9.9			
30.0	590.1	63	9.7				629.8	71	9.9			

M1 = Total new growth
M2 = No. of shoots.
M3 = Mean of shoot length.

a Sig. than control P= 0.01
b " " " P= 0.05
d " " March/April P=0.05
f " " April P= 0.05

a) All treatments produced increases over controls in total extension growth, the number of new shoots produced and in their mean length. Significant increases however only resulted from the November application at both rates in respect of the total new growth and mean shoot length.

b) At any particular rate, autumn treatments have resulted in larger increases than have spring with the exception of 30 lbs. The increase in total growth resulting from 19.5 lbs (November application) was significantly greater than that obtained from both spring applications, the increase in mean shoot length at 9.75 and 19.5 lbs being significantly greater than the April but not March treatments.

c) The increase in total growth is greater than the increase in number of shoots, so resulting in longer mean shoot length which is the reverse of the results of spring applications to gooseberries.

d) The highest application rates (October, November and March treatments) resulted in the greatest extension growth, so indicating an exceptionally high tolerance of blackcurrants to dichlobenil.

DISCUSSION.

The results of these trials indicate that a control of heavy infestations of Agropyron repens may be achieved throughout the growing season by the application of dichlobenil granules in March or April at 7.5 to 9.75 lb. Surviving rhizomes however recommence growth in the late summer/early autumn following spring treatment.

The overall effect of spring applications persisted later in the season than the overall effect of autumn applications, and within these two main periods, the later application was made, the longer into the following season the residual action persisted.

The value of an autumn application however, as reflected by the marked improvement in extension growth, bush density and general crop vigour, was clearly evident under conditions where crop growth and development had been seriously impaired by really pernicious infestations of Agropyron repens. Although subsequent regrowth occurs somewhat earlier than that following spring application, this is more than off-set by the benefits derived from earlier crop recovery, and under such conditions, an application of 9.75 lb made in November would be advantageous.

All annual weeds found on the trials were highly susceptible at 7.5 lbs with the exception of Galium aparine and Geranium dissectum which were moderately susceptible.

Of the perennial weeds encountered, Agrostis and Rumex spp and Cirsium arvense were susceptible at 7.5 lb applied autumn or spring. The control of Ranunculus repens and of Convolvulus arvensis was improved at 9.75 lb, but control of these species was achieved only by spring and not autumn application. This may be explained by the fact that dichlobenil acts primarily on actively dividing meristematic tissue, especially that found in growing points and root tips, and after application, forms a herbicidal "layer" in the top few centimetres of the soil. It is suggested that by the time Convolvulus - a late starter - is growing vigorously, the soil residues following autumn application have fallen to a level which has little effect on this spp, whereas with the later spring application, residues in the dichlobenil layer, through which Convolvulus then spears, are such that this spp is severely checked at emergence and is heavily suppressed at least until July. Data (not here presented) from a continuation of these trials in 1968 indicates a good control of Convolvulus arvensis at all spring rates of application in the second consecutive year of application.

Although Ranunculus repens is regarded as being resistant, it is note-worthy that a reduction in flowering of 50%,together with a height and density reduction of the same order was generally observed at 7.5 lbs during the season and resulted in a marked reduction in the growth and vigour of this spp.

Geranium spp was moderately susceptible to dichlobenil at 7.5 lbs, but Rubus, Heracleum and Scabiosa spp were resistant at rates up to 12.0 lbs. General weed control on light soils was better than that obtained on heavy soils.

Both gooseberries and blackcurrants appeared to be completely tolerant to dichlobenil granules at rates up to 30 lb, the bushes improving in appearance and making more extension growth as improved weed control followed increasing application rates.

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AN EVALUATION OF FOUR HERBICIDES FOR ROUTINE WEED CONTROL IN A MINIMAL CULTIVATION MANAGEMENT PROGRAMME FOR RASPBERRIES

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Summary In a raspberry plantation (var. Malling Jewel) grown on a minimal cultivation management system, atrazine and bromacil at 2 lb a.i./ac and chlorthiamid at 4 lb a.i./ac as annual overall weed control treatments were compared with simazine at 2 lb a.i./ac. No evidence of initial or cumulative adverse effects on the crop over a four year period was found although in 1967 plots treated with bromacil gave a significantly lower ($P = 0.05$) fruit yield than plots treated with simazine. All three herbicides gave excellent control of annual and perennial weeds throughout the trial. One or other of the three herbicides could usefully be introduced at maintenance rates into the weed control programme at an early stage of perennial weed infestation so that weeds do not build up to a level where they threaten the continuance of normal plantation management and require drastic control measures.

INTRODUCTION

Minimal cultivation systems of growing raspberries have developed mainly around the use of the herbicide simazine (Robinson, 1964a, 1964b; Stephens, 1964). Widespread and regular use of simazine has, however, brought to light the need for alternative herbicides to control resistant annual and perennial weeds. In this experiment, adapted from one laid down by Stephens (1964), atrazine, bromacil and chlorthiamid were compared with simazine as the herbicide components in a minimal cultivation management programme of the type used by leading Scottish growers.

METHODS AND MATERIALS

The experiment was planted on 7th April 1964 in a medium sandy loam soil. A randomised block design was used with six replications of the four herbicide treatments. Single canes of the variety Malling Jewel were planted 2 ft apart in 6 ft rows, giving 2 rows each 54 ft long per plot with single guard rows between plots. The harvested area per plot was 72 yd^2.

Herbicide treatments were as follows:

Treatment	Dose lb a.i./ac.	Formulation
Simazine	2	50% wettable powder
Atrazine	2	4% granular
Bromacil	2	80% wettable powder
Chlorthiamid	4	7½% granular

Application was made overall to both rows and alleys. Simazine and bromacil were applied in 40 gal/ac on 23rd April and the granular formulations by hand on 14th May in 1964. Repeat applications were made every April thereafter.

The plantation was grown on the stool system, but unlike commercial practice no attempt was made to limit spawn growth in the rows during the growing season. During the winter, spawn growing between the stools was dug out ('stooling up'), old cane and weak or broken new growth in the stools cut out and, when necessary, new stool cane thinned. Once the plantation became established canes were tipped at 5 ft. Suckers in the alleys were controlled as required by applications of paraquat/diquat at 1 lb a.i./100 gallons water. This treatment was supplemented by mowing any surviving sucker growth in the alleys just prior to fruit picking. Scattered small patches of perennial weeds, mainly _Tussilago farfara_, were present across the trial area at planting time.

All plots received a standard raspberry fertiliser application in April every year.

During the winter records were taken of potential fruiting cane produced per plot, _i.e._, cane left after stooling up and removing weak or broken growth in the stools. In the first years virtually all healthy cane was tied in. Cane growth in 1966 was sufficient to require thinning of some stools before tying in and records were also taken after tying in and tipping. Yields of fresh fruit and, in 1967, 100 berry weight were recorded for each plot.

Numbers and heights of suckers were recorded on 4 x 1 sq.yd. quadrats in the centre alley of each plot. Weed results relate to the whole area of the centre alley of each plot.

RESULTS

Crop response Treatment with atrazine, bromacil or chlorthiamid had no adverse effects on crop growth during the 1964 or 1965 growing seasons. There were no significant differences between any of these three treatments and the simazine treatment in terms of cane production in 1964 or 1965 or in the yields obtained from that cane in the next season (Table 1). Table 2 shows that in 1967 plots treated with simazine gave the highest yields, but only plots treated with bromacil yielded significantly (5% level) less fruit. Plots treated with simazine produced slightly more cane than other treatments in 1966 and this difference still persisted after thinning and tying in. Differences between treatments in terms of numbers of canes produced, canes tied in, average height after tipping, 100 berry weights and yield of fruit per cane were, however, not statistically significant. The experiment was terminated during the winter of 1967-8 but, to check whether the 1967 difference in yield between simazine and bromacil might be repeated, the numbers and lengths of canes produced during 1967 were recorded and the percentage of these reaching the top wire used as an estimate of quality. These figures show no significant difference between treatments, nor do the

Table 1.

Cane and fruit records 1964-66

Treatment	1965 Canes per plot	1965 Average length (in.)	1965 Yield cwt/ac.	1966 Canes per plot	1966 Average length (in.)	1966 Yield cwt/ac.
Simazine	86.66	37.62	23.99	173.00	57.53	63.03
Atrazine	81.66	35.94	21.60	174.34	55.66	60.41
Bromacil	86.34	36.66	25.14	181.34	56.19	63.74
Chlorthiamid	86.66	34.18	20.83	167.66	54.32	64.65
Sig.Diff. (P=0.05)	NS	NS	NS	NS	NS	NS
Coeff of variation %	9.69	6.33	13.58	10.03	3.84	8.19

Table 2.

Cane and fruit records 1967

Treatment	Canes tied in/ plot	Average length after tipping (in.)	Yield cwt/ac.	Yield/ cane tied in (gms)	100 berry wt. (gm.)
Simazine	224.66	56.86	78.74	267.71	351.17
Atrazine	208.16	56.35	73.09	266.72	339.08
Bromacil	213.34	55.78	69.86	249.91	335.58
Chlorthiamid	213.34	55.98	76.31	271.87	345.17
Sig.Diff. (P=0.05)	NS	NS	6.87	NS	NS
Coeff of variation %	8.04	2.11	7.45	6.92	3.94

cumulative yield data for the three harvest years. (Table 3).

Table 3

Canes produced 1967 and cumulative yield 1965-67

Treatment	Canes produced /plot	Average length (in.)	% reaching top wire (Ang. trans.)	Cumulative yield cwt/ac.
Simazine	356.00	59.74	54.66	165.76
Atrazine	385.66	58.48	50.58	155.10
Bromacil	363.34	58.38	52.61	158.74
Chlorthiamid	344.34	56.66	53.25	161.79
Sig.Diff. (P=0.05)	NS	NS	NS	NS
Coeff of variation %	12.12	5.32	7.27	6.07

Samples of fruit from the 1967 harvest were assessed for taint by the Fruit & Vegetable Preservation Research Association. No taints were detected in any of the samples.

In 1966 and 1967 the first flush of alley suckers on plots treated with bromacil showed slight yellowing, while alley suckers on plots treated with chlorthiamid were shorter than those on any other treatment. These symptoms were outgrown as the season progressed.

Weed Control All the herbicide treatments gave excellent control of annual weeds from 1964 until the end of the experiment. Atrazine granules were slow to act in 1964 until incorporated by shallow hand-hoeing. In plots treated with simazine *Galium aparine* began to build up in the rows; otherwise the main difference between treatments was in terms of perennial weed control. The assessment of perennial weed control by the residual herbicides was complicated by the regular applications of paraquat/diquat to the alleys during the growing season and the mowing of the alley sucker growth before picking. A survey in October 1965 showed that *Tussilago farfara* was increasing in plots treated with simazine, while *Agropyron repens* and *Cirsium arvense* were also present in patches. Very few weeds were found on plots treated with the other herbicides. In October 1966 annual weeds were of virtually no importance and *Tussilago farfara* was the dominant weed on plots treated with simazine. (Table 4). An assessment made on the first flush of perennial weeds in April 1967 again indicates the superiority of the other herbicides over simazine, particularly in the control and prevention of spread of *Tussilago farfara*. Bromacil and chlorthiamid had eliminated this weed completely, while atrazine had reduced it by nearly 90% compared with simazine.

Table 4

Weed records per centre alley (Treatment means).

Treatment	% bare ground 28/10/66	% cover by perennial weeds 28/10/66	No. of Coltsfoot shoots 25/4/67	No. of Thistle shoots 25/4/67	Couch grass. No. of yd^2. infested 25/4/67
Simazine	84	15	216	33	2
Atrazine	95	5	27	23	0
Bromacil	100	0	0	9	0
Chlorthiamid	92	5	0	0	2

DISCUSSION

The results show that any of the three herbicides, in the formulations and at the doses used, could usefully have been substituted for simazine in the herbicide programme. They had no adverse effect on the newly planted cane, showed no signs of a gradual build up of toxicity to the crop over 4 years of application and produced no taint problem. Compared with simazine bromacil depressed the yield in 1967 but examination of 1967 cane records does not suggest that this was the beginning of a decline in crop vigour. The difference is not attributable to any single factor; the slightly greater number of canes produced and tied in on the plots treated with simazine and the lower yield per cane on plots treated with bromacil probably contributed to it.

The effect of chlorthiamid on alley sucker growth in spring is possibly related to the stunting effect noted at some sites by Allen (1966).

On plots treated with simazine, the perennial weed population, mainly <u>Tussilago farfara</u>, built up steadily over the years, despite regular alley treatment with paraquat/diquat during the main growing season. Had the experiment continued it would soon have become necessary to revert to cultivation or to introduce treatment with one of the other herbicides to eliminate weed competition. None of the other treatments completely eliminated perennial weeds, although bromacil came very close to it, but they all kept the population sufficiently low to avoid any necessity for interference with the system of plantation management. The rate of bromacil used in this experiment was probably rather high in comparison with the other herbicides and it would be worthwhile examining the performance of the herbicide at an annual rate of 1 lb a.i./ac. This would also raise the safety margin on the crop and reduce the possibility of a build up of residues of bromacil in the soil. The persistence of residues in soils treated with repeated annual applications of the four herbicides used in this experiment is being investigated.

Atrazine, bromacil and chlorthiamid at the rates used in this experiment are more expensive than normal rates of simazine and are unlikely to replace it as a routine plantation maintenance treatment. However, where growers find it impossible to eradicate perennial weeds before planting, or where these begin to build up as light overall infestations in established plantations, the results of this experiment suggest that one of these three herbicides could usefully be substituted for simazine for one or more years, without adverse effect on the crop. This type of preventative treatment might prove more economical in the long run than continuing with simazine until the weed infestation reaches a level where crop vigour is affected and the minimal cultivation programme has either to be abandoned or rescued by the application of higher and potentially more phytotoxic dosage rates of the same or other herbicides.

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PRELIMINARY TRIALS WITH TERBACIL FOR WEED CONTROL IN SOFT FRUITS

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Summary Blackcurrants, gooseberries, raspberries, blueberries and strawberries showed marked differences in susceptibility to terbacil. Young blackcurrant plants and newly planted strawberries were very sensitive. Raspberries and blueberries showed good tolerance even to doses in excess of those needed for weed control. Gooseberries were intermediate in their reaction but both young and well established bushes were uninjured by terbacil at 1 or 2 lb/ac.

Although generally less selective than simazine, terbacil was much more effective against some weeds, e.g. *Agropyron repens* and *Lathyrus pratensis*, than similar doses of simazine. Terbacil appears promising as a spot treatment for the control of certain simazine-resistant weeds in well established raspberries, blueberries and gooseberries.

INTRODUCTION

The problem of controlling perennial weeds in bush and cane fruits is now less acute following the introduction of chlorthiamid and dichlobenil. Nevertheless, a wider range of herbicides is desirable to enable growers to change occasionally the herbicides used. This helps to lessen the risk of a build up of resistant weed species and also of the accumulation of residues of any one herbicide.

Following preliminary reports on the effect of terbacil on a wide range of annual and perennial weed species, a series of experiments was laid down in the Soft Fruit Research Centre, Clonroche, Co. Wexford, to obtain information on the tolerance of blackcurrants, gooseberries, raspberries, blueberries and strawberries to this herbicide and also to investigate its effect on weeds.

MATERIALS, METHODS AND RESULTS

Experiment 1

Terbacil and simazine were compared on blackcurrants, cultivar Baldwin. Cuttings planted in November, 1965 were sprayed on 5 May, 1966 using a logarithmic sprayer. Terbacil was applied at doses of 3 lb to 0.13 lb/ac and simazine at 6 lb to 0.25 lb/ac. Terbacil caused very severe injury even on plants treated with the lowest dose (0.13 lb/ac). No leaf injury or check to growth was recorded on simazine-treated plots.

Experiments 2 and 3

The first experiment on gooseberries was carried on the cultivar Careless, which had been planted in February, 1960 and used in a cultural trial until 1966. The plantation had been treated uniformly in 1967, being kept clean by simazine and spot treatment with paraquat. The bushes were of uniform size and vigour when the terbacil trial was laid down in February, 1968. The treatments listed in Table 1 were applied on 23 February, 1968. Simazine, which is a recommended herbicide for gooseberries (Fryer and Evans, 1965) was applied at 2 lb/ac as a control.

The bushes were spaced 4½ ft apart in rows 9 ft apart. Each plot consisted of four bushes, with a 3 ft sprayed strip on each side of the gooseberry row. A randomised block design was used with 9 replications.

A second experiment was carried out on gooseberries, cultivar Careless, which had been planted in November, 1966. The bushes were spaced 4 ft apart in rows 9 ft apart and each treatment was applied to a 5 bush plot, 20 ft long. A fully random design with 4 replications was used. The ground was kept clean in 1967 by means of simazine and paraquat. The treatments listed in Table 1 were applied on 19 February, 1968 to strips 3 ft wide on each side of the gooseberry row.

In both experiments terbacil at 4 lb/ac caused severe damage to the plants. The damage showed up in mid May as a lightening and clearing of the veins of the leaves. This was followed in late May by marginal and interveinal necrosis which resulted in considerable defoliation by mid-June. During late June many of the bushes began to recover. The young unfolding leaves no longer showed any signs of herbicide damage. In Experiment 2 the older bushes made a fairly complete recovery by early August, many of the young shoots having made 6 in. or more of growth completely free from signs of herbicide damage. The younger bushes in Experiment 3 did not show the same degree of recovery. During early August many of the bushes treated with terbacil at 4 lb/ac were defoliated except for a few leaves at the tips of the young shoots. Similar symptoms, though less severe in degree, showed up on the plants receiving 3 lb/ac. However, with these the defoliation was not so severe and recovery at the end of the season was complete. Some slight vein clearing also occurred on a few bushes that were treated with 2 lb/ac but phytotoxic effects were absent on the plants receiving 1 lb/ac.

The effect of terbacil on the yield of gooseberries is shown in Table 1.

Table 1

Experiments 2 and 3 - Effect of terbacil on yield of gooseberries

Herbicide (lb/ac)	Established bushes (Experiment 2) (cwt/ac)	Young bushes (Experiment 3) (cwt/ac)
Simazine 2	89.0	32.3
Terbacil 1	92.9	36.0
2	93.1	35.5
3	79.6	35.0
4	62.5	19.6
'F' test	**	**
S. E.	± 5.47	± 3.13
df	32	15

The yield of the young bushes was significantly reduced by terbacil at 4 lb/ac compared with simazine ($p < 0.05$) and the remaining terbacil treatments ($p < 0.01$). When applied to the well established gooseberries the 4 lb dose again gave significantly lower yields than terbacil at 3 lb ($p < 0.05$) and the remaining treatments ($p < 0.01$). Yields from plots treated with simazine and with terbacil at 1, 2 and 3 lb/ac respectively did not differ significantly in either experiment.

Terbacil gave excellent weed control in both experiments. At the lowest dose (1 lb/ac) it completely suppressed *Lathyrus pratensis*, a weed which was prevalent in all simazine-treated plots. However, it failed to give any control of *Vicia cracca*, even at the highest dose. *Viola arvensis* was also resistant to doses of 1 and 2 lb/ac.

Experiment 4

This experiment was laid down on a block of Cambridge Vigour strawberries which had been planted on 10 May, 1966. The strawberries had been used for trials with chloroxuron and diphenamid in 1966 and 1967 but none of these previous treatments had had any adverse effect on plant size or crop yield. The treatments listed in Table 2 were applied on 24 April, 1968. Lenacil 1 lb/ac was included as a control treatment. Each plot consisted of two drills with 25 plants on each drill. The drills were spaced 34 in. apart and the plants 18 in. apart. Each treatment was replicated six times in a randomised block design.

Terbacil at $\frac{3}{4}$ and 1 lb/ac caused severe damage to the strawberry foliage. On plants treated with the highest dose, the damage became apparent during early May as scorching of the outer edges of the leaves. Similar, though less severe symptoms occurred on plants treated with $\frac{3}{4}$ lb/ac. The symptoms became progressively worse until late May. Subsequently the plants made a good recovery and by mid-August all evidence of foliar damage had disappeared. The $\frac{1}{2}$ lb/ac dose resulted in a slight amount of leaf scorch.

All terbacil treatments caused a considerable, though not always significant, reduction in yield (Table 2). Terbacil at 1 lb/ac significantly decreased yield compared with the $\frac{3}{4}$ lb/ac ($p < 0.05$) and $\frac{1}{2}$ lb/ac treatments and with lenacil at 1 lb/ac($p < 0.01$). There was no significant difference between lenacil at 1 lb/ac and the two lower doses of terbacil.

Table 2

Effect of terbacil on yield of strawberries, cultivar Cambridge Vigour

Herbicide 24.4.68	(lb/ac)	Yield (cwt/ac)
Lenacil	1	180.3
Terbacil	$\frac{1}{2}$	168.0
"	$\frac{3}{4}$	159.5
"	1	129.4
'F' test		**
S.E.	(df = 15)	$\pm$ 8.85

Weed counts made in early August showed that the herbicide treatments gave satisfactory control of all annual weeds present, mainly *Poa annua* and *Stellaria media*. The higher doses of terbacil gave slightly better control of perennial grasses, mainly *Holcus lanatus* and *Agrostis stolonifera* than did lenacil or the lower doses of terbacil.

Experiment 5

In this experiment the effect of terbacil on newly planted strawberry runners was examined. The runners, cultivar Cambridge Vigour, were spaced 18 in. apart on 34 in. drills. The runners were planted on two different dates, viz. 14 November, 1967 and 29 February, 1968 and were treated with the herbicides listed in Table 3 on 20 November, 1967 and 21 March, 1968 respectively. Herbicides were applied by means of a logarithmic sprayer in a volume of 40 gal/ac. Each plot was 1 drill 24 yd long and comprised 48 strawberry plants. Treatments were randomised in three separate blocks.

All terbacil and simazine treatments caused severe damage. First signs of injury to both November and February planted strawberries occurred in early April. This consisted of marginal and interveinal necrosis of the leaves. The symptoms became progressively worse and by early May many of the treated plants were dead or dying. During late May the less severely damaged plants began to recover. By early August most surviving plants were comparable in vigour with untreated controls.

The percentage of plants surviving the different doses of simazine and terbacil in mid August is shown in Table 3.

Table 3

Effect of terbacil and simazine on young strawberries

Treatment	(lb/ac)	Percentage plants surviving in August 1968*			
		November planted (sprayed 20. 11.67)		February planted (sprayed 21. 3.68).	
		with charcoal	without charcoal	with charcoal	without charcoal
Terbacil	3.5 - 2.9	42	0	39	6
"	2.9 - 2.4	67	0	39	11
"	2.4 - 1.6	79	25	55	33
"	1.6 - 1.2	92	33	61	11
"	1.2 - 0.88	88	67	66	22
"	0.88 - 0.64	100	100	72	55
"	0.64 - 0.47	100	92	100	66
Simazine	3.5 - 2.9	100	17	94	83
"	2.9 - 2.4	100	37	94	72
"	2.4 - 1.6	100	50	100	78
"	1.6 - 1.2	100	71	100	100
"	1.2 - 0.88	100	83	100	94
"	0.88 - 0.64	100	96	94	100
"	0.64 - 0.47	100	100	89	100

* Mean of 3 replications

The results show that terbacil was, in general, slightly less damaging when applied in November than in February. This was probably due to the reduction in the concentration in the root zone of the November-applied terbacil by the time active growth began in March. Charcoal dipping provided some degree of protection from terbacil but was less effective with this herbicide than with simazine. Contrary to expectations, simazine, used on plants that had not been dipped in charcoal, caused more damage when applied in November than in March.

Experiment 6

Terbacil was applied with a logarithmic sprayer at 8 to 0.8 lb/ac on raspberry varieties Norna and Veten. Plot length was 64 ft with Veten and 45 ft with Norna. The herbicide was applied on 29 March, 1968 to a strip 18 in. wide on both sides of the plant row. Records were kept of herbicide injury symptoms and crop yield.

Terbacil at doses above 4 lb/ac caused some scorching of the edges of the lower leaves of young canes of variety Veten in early June. No further scorching occurred after mid-June and the treatment did not result in any loss in vigour. No such symptoms occurred on the variety Norna.

Yields in the experimental area were rather variable but there was no evidence of yield reduction of either variety on plots treated with terbacil at doses less than 5 lb/ac. The yield of Veten was slightly reduced where doses higher than 5 lb/ac were used.

Experiment 7

Nine year old bushes of blueberries (unnamed seedlings) were treated with terbacil at 1, 2, 3 and 4 lb/ac and simazine 2 lb/ac on 26 February, 1968. The bushes were spaced 3 ft apart in rows 9 ft apart and the spray was applied to a strip $1\frac{1}{2}$ ft wide on each side of the bush row. A fully random design with four replications was used.

Crop yields were not recorded but there was no evidence of any herbicidal effect on the foliage or vigour of the bushes during the season.

Experiment 8

To examine the effect of terbacil on established grass weeds doses of 1, 2, 3 and 4 lb/ac were applied to an area of neglected grassland on 23 April, 1968. Simazine at 2 lb/ac and untreated control plots were also included. The dominant species at time of spraying were *Agrostis stolonifera*, *Holcus lanatus*, *Festuca rubra* and *Dactylis glomerata*. Other species present included *Arrhenatherum elatius*, *Ranunculus repens*, *Cirsium arvense*, *Lotus corniculatus* and *Achillea millefolium*. The plot size was 5 yd x 2 yd, and each treatment was replicated in four randomised blocks. The weeds present were recorded on 27 May and 13 August.

First signs of damage caused by herbicides on broad leaved weeds appeared on 29 April. *Ranunculus repens* was most severely affected, the older leaves showing severe blackening. This symptom occurred only on plots receiving terbacil at 3 or 4 lb/ac. Some scorching of the tips of grasses were also apparent on these plots.

By 27 May almost all grasses, both annual and perennial had died on all terbacil-treated plots. *Agropyron repens* still survived on this date in a much weakened state but was dead by mid-June.

Following the initial check the perennial broad-leaved weeds quickly recovered. By early June *Ranunculus repens* and *Cirsium arvense* were colonising the areas vacated by the grass species on all terbacil-treated plots. By early August the plots treated with the lowest dose were almost completely recolonised. The grass weeds showed no signs of recovery by mid-September. The simazine treatment had no obvious effect on the flora of the treated areas.

DISCUSSION

Although these results are from preliminary experiments only, they show clearly that soft fruits differ markedly in their sensitivity to terbacil. Blackcurrants are very susceptible and there appears to be little place for terbacil in the crop, particularly in view of its tolerance to a wide range of alternative herbicides (Fryer and Evans, 1968). Raspberries and blueberries showed good tolerance to terbacil even at doses much higher than those required for weed control. Gooseberries were intermediate in their reaction. However, the damage only occurred where high doses of 3 and 4 lb/ac were used and the injury appeared to be short lived on most bushes.

Terbacil shows some promise, therefore, for use in raspberries, blueberries and gooseberries against perennial weeds that are tolerant to simazine and other herbicides. For example, Lathyrus pratensis is becoming a troublesome weed in some plantations that have been sprayed repeatedly with simazine. The results suggest that terbacil may be useful as an occasional treatment against this weed.

The effect of terbacil on Agropyron repens and Agrostis stolonifera is particularly interesting, as these weeds are also tending to increase in some herbicide-treated plantations. An effective herbicide against Agropyron repens in strawberries would be especially valuable in some areas where this crop is grown as part of a farm rotation. The results show that the tolerance of strawberries to terbacil is poor even at doses as low as 0.5 lb/ac. Nevertheless, Agropyron repens is likely to occur in patches only, where spot treatment methods of control are feasible. Moreover, the strawberry has the ability to fill up gaps in a crop by the growth of runners from uninjured plants. Because of the difficulties of controlling this weed by cultivation and the absence of suitable chemical methods of control, further work with terbacil in strawberries would be justified.

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HERBICIDE EVALUATION TRIALS ON RASPBERRY AND ROSE ROOTSTOCKS

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Summary Two trials are described, one on newly planted raspberry (cv. Malling Jewel), the other on rose rootstocks, Rosa canina pollmeriana. Both were conducted at Begbroke Hill on a sandy loam soil during the 1967 season when rainfall was below average from June to August. Herbicides were applied in the spring following planting.

On raspberry all treatments caused contact injury of the foliage present at the time of spraying. Terbacil gave the best weed control, but at 1 lb/ac reduced the number of canes that were subsequently produced. At 0.5 lb/ac weed control was almost as good and there was no effect on cane production. The other treatments, 2-azido-4-ethylamino-6-t-butylamino-1,3,5-triazine (WL 9385) at 0.5 and 1.0 lb/ac, 1,1-dimethyl-3-[3-(N-tert butylcarbamyloxy)phenyl] urea (NIA 11092) at 0.5 and 1.0 lb/ac and 2-(α-napthoxy)-N,N-diethyl propionamide (R 7465) at 1 and 3 lb/ac all failed to control several common annual weeds. R 7465 at 3 lb/ac reduced cane length.

On rose rootstocks terbacil at 0.5 to 4 lb/ac, chlorthiamid at 4 to 12 lb/ac and simazine at 2 lb/ac gave good control of annual weeds. Terbacil and chlorthiamid caused appreciable reduction in stem diameter and plant weight at doses above 0.5 and 4 lb/ac respectively.

INTRODUCTION

For several years simazine has been used for the control of annual weeds in raspberries and rose rootstocks. The repeated use of simazine to the exclusion of all other herbicides associated with the abandonment of mechanical weed control has often resulted in an increase of certain annual weeds such as Atriplex patula and Polygonum aviculare, and perennial weeds which are partially or totally resistant to simazine. This problem although most serious in long-term perennial crops such as raspberry also occurs in short-term perennials such as rose rootstocks, especially where successional crops are propagated on the same ground.

In an attempt to find alternatives to simazine crop tolerance to several new herbicides have been investigated at Begbroke Hill. In the two trials that are described, newly planted raspberry and rose rootstocks, growing in a sandy loam soil were treated with herbicides in the spring following planting.

METHOD, MATERIALS AND RESULTS

Raspberry

Raspberry cv. Malling Jewel was planted in December 1966 and cut back to 4 in. above the ground. Four herbicides, terbacil, 2-azido-4-ethylamino-6-t-butylamino-1,3,5-triazine (WL 9385), 1,1-dimethyl-3-[3-(N-tert butylcarbamyloxy)phenyl] urea (NIA 11092) and 2-(α-napthoxy)-N,N-diethyl propionamide (R 7465) were applied on April 13th 1967 when the buds on the canes were bursting and some new suckers were emerging. Each herbicide was applied at two doses. The plots each contained twelve plants and the treatments were randomised and replicated twice. Seedling weeds up to

Table 1. Response of newly planted raspberries to four soil-applied herbicides

Treatment	Crop response			Weed response 18.5.68	
		Cane data 12.1.68 (as % of control)			
	Visual symptoms 27.4.67	No. canes per twelve plants	Mean length	% cover	Weed species surviving
Control	growth normal	100 (15 canes)	100 (3.75 ft)	60	Stellaria media, Senecio vulgaris, Matricaria spp. Capsella bursa-pastoris, Poa annua, Papaver dubium, Polygonum aviculare, barley, Aphanes arvensis
Terbacil 0.5 lb/ac	yellowing of expanded leaves	113	124	7	S. vulgaris, barley
" 1.0 lb/ac	yellowing and scorching of expanded leaves	74	111	5	barley
WL 9385 0.5 lb/ac	slight yellowing of oldest leaves	123	108	10	P. aviculare, P. annua, Matricaria spp., S. media, barley
" 1.0 lb/ac	marginal yellowing and scorch of expanded leaves	103	99	10	S. vulgaris, S. media, Matricaria spp., barley
NIA 11092 0.5 lb/ac	marginal yellowing of expanded leaves	119	108	15	S. media, C. bursa-pastoris, Matricaria spp., P. dubium, P. aviculare, barley
" 1.0 lb/ac	marginal and intervenal yellowing of expanded lvs.	97	105	7	S. media, C. bursa-pastoris P. dubium
R 7465 1.0 lb/ac	slight marginal yellowing of some extended leaves	103	105	25	P. aviculare, S. vulgaris, Matricaria spp. C. bursa-pastoris
" 3.0 lb/ac	marginal yellowing and scorch of some expanded leaves	113	84	15	A. arvensis, S. media, S. vulgaris C. bursa-pastoris, Matricaria spp.

1 in. high were present when the treatments were applied. All the treatments were applied as sprays using 50 gal/ac at 30 psi through Allman No. 1 ceramic fan jets. There was 0.71 in. rain in the week before treatment and 0.86 in. in the month following. Injury symptoms and visual estimates of weed growth were recorded throughout the season and cane measurements were made in January 1968. After assessment the plots were hand-hoed or sprayed with paraquat to prevent excessive weed growth.

Two weeks after application all the treatments resulted in chlorosis of the leaves which were unfolding when the herbicides were applied. Eight weeks after application NIA 11092 at 1 lb/ac was still causing severe injury symptoms on some plants. Growth following all the other treatments was normal. Terbacil at 1 lb/ac reduced the total number of canes and total cane length but not the mean length of surviving canes (Table 1). None of the treatments reduced the weight of cane produced. The only treatment to reduce cane length was R 7465 at 3 lb/ac. Terbacil gave the best weed control although it failed to give complete control of barley at 1 lb/ac and Senecio vulgaris at 0.5 lb/ac. The other herbicides each failed to control several annual weed species. There were no perennial weeds in this trial.

Table 2.

The response of Rosa canina pollmeriana to terbacil, chlorthiamid and simazine in 1967

Treatment	Crop response			
	Visual symptoms 1/6/67	General growth score 27/6/67	Stem diam. (% of control) 31/8/67	Weight of roots + shoots (% of control) 23/10
Control	none	0.1	100 (1.5mm)	100 (0.27 lb/plant)
Terbacil				
0.5 lb/ac	very slight marginal chlorosis	0.6	97	91
1.0 lb/ac	slight marginal chlorosis and necrosis	1.9	65	44
2.0 lb/ac	marginal chlorosis and necrosis	2.7	47	17
4.0 lb/ac	" " " "	3.1	33	6
Chlorthiamid				
4.0 lb/ac	slight marginal necrosis and reddening	1.5	85	75
8.0 lb/ac	marginal necrosis and reddening	2.4	80	53
12.0 lb/ac	marginal necrosis and pronounced reddening	2.8	75	50
Simazine				
2.0 lb/ac	none	1.4	89	85

Key to scoring scale on 27/6

0 = no effect
1 = leaf effects, no apparent reduction in growth
2 = 25% reduction in growth
3 = 50%
4 = bushes more or less dormant
5 = dead

Rose root-stocks

One year old seedlings of Rose canina pollmeriana were planted on April 12th 1967 in 1 x 1 yd plots containing two rows of four plants at 9 in. spacing. Terbacil and simazine were applied as sprays and chlorthiamid as a 7.5% granular formulation on April 27th; the doses used are shown in Table 2. The treatments were randomised in blocks and replicated three times. The sprays were applied using a square yard sprayer fitted with an Allman No 0 ceramic fan jet, at 30 psi and in 100 gal/ac. The chlorthiamid granules were weighed out for each plot and applied from a bottle with a perforated cap. At the time of treatment the buds of the rose-stocks were just breaking and there were a few weeds at the cotyledon stage present on the plots. There was 0.41 in. of rain in the week before treatment and 2.41 in. in the month following. Injury symptoms and weed growth were assessed throughout the season. Any plots which became weedy were hand hoed. Stem diameter at soil level was measured on August 31st and October 23rd when the plants were lifted and the roots and shoots weighed separately.

Two weeks after application crop growth on the chlorthiamid and simazine plots was normal but injury symptoms were recorded on the terbacil plots. They were similar to those recorded on June 1st and shown in Table 2. By this time injury was also observed on the chlorthiamid plots. Symptoms took longer to appear on the simazine plots. Reductions in stem diameter and plant weight occurred with terbacil and chlorthiamid at doses greater than 0.5 and 4.0 lb/ac respectively. The effect of treatments on stem diameter at the end of the season was similar to that recorded in August. All the herbicide treatments gave complete control of annual weeds including Fumaria officinalis, Polygonum convolvulus, P. aviculare, Trifolium repens Capsella bursa-pastoris and Matricaria spp. There were no perennial weeds present in this trial.

DISCUSSION

Raspberry

Injury symptoms were confined to the leaves that were unfolding when the herbicides were applied indicating that they were probably caused by contact action and might be avoided by earlier application. The transitory nature of the foliage symptoms on all treatments except NIA 11092 at 1 lb/ac indicate that there was either no translocation from sprayed leaves to other parts of the plant or if there was, that it did not result in damage. The rainfall during June, July and August 1967 was below average. In a wetter season, a greater downward movement of the herbicides might have caused damage to new canes. Terbacil gave the best control of dicotyledonous weeds but its failure to control barley at 1 lb/ac could be a serious drawback particularly in mulched crops. In the trial on rose rootstocks 0.5 lb/ac controlled Senecio vulgaris whereas this weed was not controlled in the raspberry trial. The reduction in the number of canes produced on the terbacil 1 lb/ac treatment might be important if it were to occur in established crops of those cultivars which do not usually produce many new canes. In an earlier trial Ivens and Clay (1966) applied terbacil at 1 and 3 lb/ac in May to suckers growing vigorously. Similar contact injury occurred and the higher dose caused death of some of the growing tips, although those that survived grew normally. Further investigations with this chemical would appear worthwhile.

Rose rootstocks

The injury symptoms caused by simazine were probably the result of heavy rain three weeks after application, when 1 in. fell in a single day. In earlier work on plants grown in pots in the same soil, the same dose of simazine did not produce visual symptoms (Ivens, 1964). Elsewhere, annual treatment with this dose of simazine on a light soil has caused no injury or growth reduction (Ewan, 1964). Because of the heavy rainfall following treatment in this experiment the damage cause by terbacil and chlorthiamid may have been more severe than in a normal season although rainfall in June, July and August was below average. The trial has however demonstrated that both herbicides can cause serious damage. In an earlier trial

Ivens and Clay (1966) applied terbacil at 1 and 3 lb/ac and chlorthiamid at 5 and 10 lb/ac to two year-old rootstocks of Rosa canina, R. rugosa and R. multiflora. These were not budded but had been cut back as usual. On this occasion terbacil caused similar visual symptoms but the effect on bush size was less marked. R. rugosa and R. multiflora appeared to be more sensitive than R. canina. Chlorthiamid caused only slight injury which was confined to R. multiflora. The response of two year-old stock may be similar to that of budded stocks since the plants had been established for more than 12 months.

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THE PERSISTENCE OF CHLORTHIAMID, LENACIL AND SIMAZINE IN UNCROPPED SOIL

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Summary The rate of breakdown of chlorthiamid at 4, 8 and 12 lb/ac and lenacil at 1, 2 and 4 lb/ac applied to a sandy loam soil in spring was compared with that of simazine at 2 lb/ac. The half lives of all the treatments were found to be less than one month and lenacil applied at 1 and 2 lb/ac was not detected after eight months. Measurable residues of all doses of chlorthiamid and simazine were still found 12 months after treatment. The growth of lettuce and buckwheat sown 14 months after treatment was reduced by 50% on plots treated with chlorthiamid at 12 lb/ac but not by any other treatment. The significance of the results in relation to soil residue problems likely to arise with the use of these herbicides in fruit crops is discussed.

INTRODUCTION

Chlorthiamid and lenacil have become widely used in the past few years as complementary herbicides to simazine for weed control in some fruit and ornamental crops. Chlorthiamid at doses up to 10 lb/ac is used for the control of annual and many perennial weeds in blackcurrants and raspberries while lenacil is used for post-planting and spring weed control in strawberries at doses up to 2 lb/ac and in a number of herbaceous perennial flower crops. Information on the rate of breakdown of these herbicides in the soil is important for an understanding of the duration of weed control likely to be obtained, and the possibility of a build-up of toxic levels in the soil and from the standpoint of the effect of soil residues on subsequent crops (Holly, 1966).

Results of studies on the persistence of chlorthiamid have been reported by Beynon et al (1966) who found that rate of breakdown was influenced by soil type and moisture conditions and that residues of up to 1 ppm remained in a peat soil a year after the application of normal rates of the herbicide. There is little experimental information on the persistence of lenacil but as its major use is in sugar beet in an annual cropping system and no carry over of toxic residues has been reported it has been assumed that there is no persistence hazard (Forrest et al, 1966). However, where the herbicide is used in strawberries the interval between treatment and the replanting of the land with a more sensitive crop can be as short as three months thus giving a greater possibility of damage.

In the investigation described in this paper the rate of dissipation in the soil of chlorthiamid at 4, 8 and 12 lb/ac and lenacil at 1, 2 and 4 lb/ac has been compared with that of simazine at 2 lb/ac. At the end of soil sampling for residue analysis, 14 months after the treatments were applied, the plots were sown with a range of sensitive crops to determine whether any remaining residues were phytotoxic.

METHODS AND MATERIALS

The experiment was carried out at Begbroke on a well drained sandy loam soil overlying a calcareous gravel to a depth of 24 to 30 in. A soil analysis is given below:

Course sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Organic matter (%)	pH
50.4	24.0	10.4	15.2	3.1	6.7

The land was ploughed the previous autumn and was then cultivated and consolidated in spring to give a fine seed bed. The experiment was laid out on a randomized block design with three replicates and a plot size of 14 x 1 yd.

Treatments

Chemical:	Formulation:	Dose: (lb/ac)
Chlorthiamid	7½% granules	4, 8 and 12
Lenacil	80% wettable powder	1, 2 and 4
Simazine	50% wettable powder	2

There were three untreated control plots in each block.

Application details

The treatments were applied on 26th April, 1967 to moist soil. The wettable powders were applied from an Oxford Precision Sprayer using Allman No. 00 fan jets at 30 psi and a volume of 100 gal/ac. The granules were applied with a 'pepper-pot' hand applicator (a screw-top bottle with a perforated lid); the amount of herbicide for each plot was weighed out beforehand.

Maintenance

The whole area was kept weed free throughout the trial by applications of paraquat to the control plots and others when necessary. Resistant weeds (mainly *Polygonum aviculare* and *Aphanes arvensis*) were removed by hand with minimum soil disturbance.

Soil sampling

The soil was sampled for chemical residues at intervals after spraying, to a depth of 0 to 2 in. and/or 0 to 4 in. Sampling times and depths are shown below:

	Interval between application and sampling in months						
	0	½	1	2	4	8	12
Depth of sample (in.)	0-2	0-4	0-4	0-2*	0-2	0-2	0-2
				0-4	0-4	0-4	0-4

* Lenacil treatments only.

The samples were taken with a modified bulb planter giving a soil core of 2¼ in. diameter. Ten cores were taken from each plot, the points being selected at random beforehand on a plan to avoid sampling the same point twice. The holes left were filled in with control soil. A double quantity of soil was removed from the control plots to provide sufficient soil for diluting treated soil in the bioassays.

Soil processing and storage

Soil from the chlorthiamid plots was sieved through an 1/8 in. mesh as soon as taken, mixed thoroughly and stored in a deep freeze cabinet at -10°C until analyzed. The other samples were air dried, put through a 1/4 in. sieve mixed thoroughly and stored at room temperature until assayed.

Residue measurement

For chlorthiamid the soils were thawed out to room temperature and thoroughly remixed: the moisture content was then determined. A representative sub-sample was extracted with 20% acetone in hexane, treated with alkaline permanganate and the 2,6-dichlorobenzonitrile measured on a Varian Aerograph 1520 gas chromatograph fitted with an electron capture detector. The method of analysis was that described by Beynon *et al* (1966) and the residues reported are total nitriles, which includes chlorthiamid and its herbicidally active breakdown product dichlobenil. The limit of detection was 0.025 ppm (equivalent to 0.02 lb/ac incorporated in a 2 in. layer of soil).

Lenacil and simazine residues were both determined by a bioassay method based on that described by Holly and Roberts (1963) but using turnip (var. Green Globe) as the test plant. The lower limits of measurement with this method varied from 0.03 to 0.06 lb/ac for lenacil and 0.02 to 0.04 lb/ac for simazine. The assay took two to three weeks.

The residue present in the 2 to 4 in. layer was estimated by difference where samples from both 0-2in. and 0-4 in. had been taken at the same time.

Field assessment of residues

As a check on the phytotoxicity of any residues remaining in the soil at the end of the experiment the area was cultivated to a shallow depth of 1 to 1.5 in. and was sown on 5th July, 1968 with four crops regarded as likely to be sensitive to the chemicals. The crops were lettuce (var. Borough Wonder), turnip (var. Green Globe), perennial rye grass (var. S23) and buckwheat. The growth of each crop was assessed at intervals by taking height and spread measurements.

RESULTS

The results of the residue determinations are shown in Figure 1. With all the herbicides, a very rapid loss of herbicide occurred during the first months followed by a slower breakdown rate through the remainder of the year. With chlorthiamid there appeared to be no difference in breakdown rate between the three doses but with all doses there was a measurable residue present in the soil in the following spring. Residues of lenacil were not found after eight months in the 1 and 2 lb/ac treatments and the amount of herbicide remaining in the 4 lb/ac treatment was below the limit of measurement after 12 months. The amount of simazine recovered immediately following spraying was low (60%), but measurable residues were still present after 12 months.

There was only slight penetration of chlorthiamid into the 2 to 4 in. soil layer when measured 2, 4, 8 and 12 months after treatment. Quantities were generally of the order of 0.05 lb/ac. No measurable amounts of lenacil and simazine were found below 2 in. at the dates where two depths were sampled.

When the growth of the test crops was assessed two months after sowing, the only treatment to give a definite effect was the 12 lb/ac chlorthiamid treatment. There was a 50% growth reduction with lettuce and buckwheat but no marked effect with the other crops.

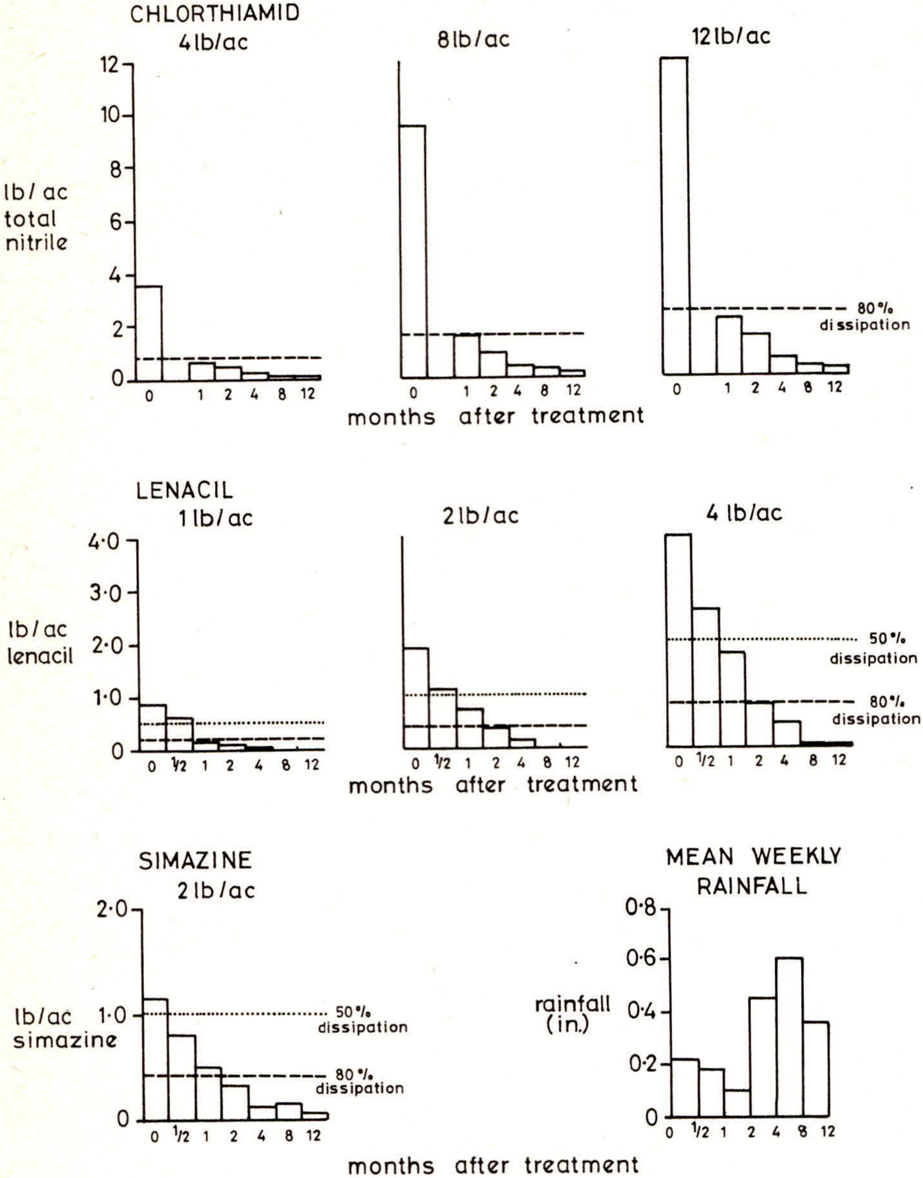
DISCUSSION

Recovery of herbicides immediately following application

The values for the recovery of the herbicides following treatment of the soil show some differences. The amounts of chlorthiamid recovered from individual replicates immediately following treatment were variable and, in the case of the 8 lb/ac treatment higher levels were found than expected. This variation was probably attributable to the volatility of the herbicide and the difficulty of mixing the moist soil samples and granules evenly before sub-sampling for analysis. There was good agreement between samples from the three replicates at later sampling dates. These same features were shown in the analysis of lenacil residues, there being wide variation in the residues measured in the first sample but good agreement between replicates at later sampling dates.

The amount of simazine recovered at the time of spraying was much less than the dose applied. A figure of only 60 to 70% recovery of simazine has been commonly found in experiments of this type where the herbicide has been determined both by bioassay and by chemical methods (Kirkland, 1968). It cannot wholly be accounted for by errors in spraying or sampling since in this experiment the lenacil treatments were applied, sampled and processed in the same way and showed good recovery. Significant losses by volatilisation and photochemical degradation have not been reported

Fig 1. Dissipation of chlorthiamid, lenacil and simazine in soil.



for simazine over such a short time period (Kearney et al, 1964) which suggests the result may be connected with strong adsorption onto the soil.

Breakdown rates

The half lives of all three chemicals in the experiment were short. For chlorthiamid the half life of less than four weeks agrees with the results of Beynon et al (1966) who found half lives varying from 1 to 12 weeks but an average of only 2 weeks for loam soils in moist conditions. The treatment was applied rather later in the year (26th April) than that recommended for the most effective herbicidal action; if the herbicide had been applied in early spring when soil temperatures were lower, the initial breakdown rate might be much less.

The half lives of around 2 weeks for the two lower lenacil rates and for simazine were short, a reflection of the warm moist soil conditions following spraying. Half lives reported for simazine in English conditions are generally longer than this (Holly and Roberts, 1963; Kirkland, 1968) but their original dose is taken as that recovered after spraying not that applied. If the results in this experiment are expressed in terms of the initial quantity of simazine recovered the half life and time for 80% disappearance would still be comparatively short (less than 1 month and 4 months respectively).

There was some indication with lenacil that the rate of breakdown was slower as the dose rate increased. Dissipation rates for soil acting herbicides have generally been found to be independent of the dose applied for the range of doses used in practice (Holly and Roberts, 1963).

Penetration into the soil

The presence of only small residues of chlorthiamid below 2 in. depth agrees with the results of Beynon et al (1966) who found most of the chemical in the surface layer of the soil.

Persistence of small residues over a long time period

The presence of measurable residues of chlorthiamed in the soil 12 months after treatment indicates that there can be a soil residue problem where sensitive crops are grown in soil on which the herbicide has been used. This possibility is supported by the growth reduction found in sensitive crops sown on the 12 lb/ac plots 14 months after treatment. In practice earlier application of the herbicide, the presence of a crop and deep cultivation of the land before replanting could all reduce the residue hazard. The presence of a crop does not, however, always lead to a reduction in residue levels (Kirkland, 1968); in dry periods, moisture levels are often much less under a vigorously growing crop thus reducing herbicide breakdown. The results reported by Beynon et al (1966) suggest that persistence may be longer in soils with a high organic matter content on which the chlorthiamid is strongly adsorbed.

Residues of lenacil would not appear to pose a serious risk but in dry seasons with a short time period between treatment and planting the next crop, injury might result. Persistence of lenacil might also be longer on soils with a higher clay content on which the chemical is more strongly adsorbed.

Similar considerations apply to simazine with which there has been much more experience. Small amounts of chemical persist longer than with lenacil but providing normal doses have been applied and the ground is well cultivated before replanting, it should be safe to plant any crop a year after treatment and many crops much sooner.

Acknowledgements

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Proc. 9th Brit. Weed Control Conf. 1968

THE RESPONSE OF APPLES, PEARS AND PLUMS TO SHOOT APPLICATIONS OF GROWTH-REGULATOR HERBICIDES

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Summary The effects of shoot treatments with a range of growth-regulator herbicides of possible use for control of perennial dicotyledonous weeds in orchards have been determined on apples, pears and plums. Treatments at different dose rates and times in the growing season have been compared.

With apples and pears there is some decrease in the degree of dieback and an increase in re-growth of treated shoots from applications of the herbicides made later in the season; the differences are not regarded as sufficient to preclude careful spraying for tree-base weed control earlier in the season. In apples 2,4-D was found to cause less damage to Worcester, Cox and Lord Lambourne, than other herbicides, but to be translocated down the shoots of the variety Bramley and produce formative effects on leaves growing out one and two years after treatment.

Pears and plums were rather more susceptible to injury than apples, but effects were generally restricted to the treated part of the shoots. 2,4-D and 2,4-DB caused severe formative effects on pears on shoots arising below the treated zone one and two years after treatment.

INTRODUCTION

The question of the susceptibility of top fruit to damage from growth-regulator herbicides has become of greater importance with the increased use of these herbicides in orchards to control certain perennial weeds. Earlier work (Luckwill and Campbell, 1957; Ivens and Clay, 1966) has shown that varieties of apples differ in their tolerance of foliar applications of growth-regulator herbicides; the relative effects of the different growth-regulator herbicides also varied according to the variety treated. It was clear that other factors were important in determining the degree of injury, notably the timing of the treatment during the growing season. In the work reported in this paper the effects of different times of application of the herbicides during the summer have been investigated on apples and pears, and the response of apples, pears and plums to a range of growth-regulator herbicides has been determined. The treatment dates have been restricted to the period from mid- to late-summer when spraying against perennial weeds would be likely and the concentrations of the herbicides have generally corresponded to those used in such operations.

METHODS AND MATERIALS

The varieties and cultural details of the apple experiments carried out at Begbroke have been described (Ivens and Clay, 1966). A further planting of Bramley was made in March 1967.

Maiden pear trees of varieties Williams' Bon Chrêtien (on Quince A) and Conference (on Quince A) at 2 x 2 yd spacing, and plums of variety Pershore

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Yellow Egg (on Myrobalan B) at 3 x 3 yd spacing were all planted in March 1966. The trees were pruned back each winter to provide young shoots of a suitable type for applying the treatments.

Normal fertilizer and pesticide applications were made for each crop. Weed control was maintained by overall applications of simazine at 2 lb/ac each spring (1 lb/ac under plums) and by spot treatments with paraquat.

The herbicides used are listed under each experiment; the same formulations were used throughout and all concentrations given are the weight per volume of the active ingredient.

Each treatment was applied to four shoots on separate trees; these trees had generally had single shoot treatments the previous year but as the effects were localized to the treated branch it was assumed that the treatment of different branches in 1967 would not lead to any interaction. At each time of treatment there was a full complement of leaves and no sign of senesence. The 9 in. tip of one shoot on each tree was treated, a tag being tied at the 9 in. mark and the shoot was then dipped in the herbicide solution and excess lightly shaken off. Precautions were taken to avoid run-off on to other parts of the tree.

Leaf number was counted at the time of treatment and assessments made of epinasty, stem bending, leaf necrosis, shoot dieback and regrowth at intervals following the application. Growth was also measured on comparable shoots on untreated trees.

Details of the particular experiments are given below.

Experiment A. The effects of 2,4-D, MCPA and 2,4,5-T applied in June, July and September, 1967 to four varieties of apple.

Chemical treatments and formulations
2,4-D (amine), MCPA (Ksalt), 2,4,5-T (ester) all at 0.1%.

Varieties
Lord Lambourne (Lam.), Cox (Cox), Worcester Pearmain (Worc.) and Bramley Seedling (Bram.) (maiden and established trees). Only 2,4-D was applied to the established Bramleys.

Dates of Application
A. 14.6.67, B. 26.7.67. C. 6.9.67
Owing to the shortness of the shoots the maiden Bramleys were not treated at the first date.
The final assessment of dieback and regrowth was made on 21.6.68.

Experiment B. The effect of a range of herbicides on four varieties of apples.

Chemicals	Formulation	Concentration (%)	Varieties
2,4-D	amine	0.10, 0.20	Lam., Cox, Worc., Bram.
MCPA	K salt	0.10, 0.20	Lam., Cox, Worc., Bram.
MCPB	Na salt	0.15, 0.30	Lam., Cox, Worc.
2,4-DB	Na/K salt	0.15, 0.30	Lam., Cox, Worc.
mecoprop	K salt	0.20, 0.40	Lam., Cox, Worc.
dichlorprop	amine	0.20, 0.40	Lam.
2,4,5-T	ester	0.10, 0.20	Lam.
2,3,6-TBA	Na salt	0.10, 0.20	Lam.
dicamba	amine	0.10, 0.20	Lam.
picloram	K salt	0.10, 0.20	Lam.

All the treatments except MCPA were applied on 2.8.66 in dry weather. MCPA was

applied on 29.7.66 and the treatment was followed by a heavy shower half an hour later.
The final assessment of dieback and regrowth of the treated shoots was made on 31.5.67.

Experiment C. The effect of five growth-regulator herbicides on Williams' and Conference pears at two dates of application.

The following dose rates were used:

2,4-D, MCPA at 0.017 and 0.05%
2,4-DB, MCPB at 0.025 and 0.075%
mecoprop at 0.033 and 0.10%

Treatments were applied to both varieties on 21.7.67 and to a further set of Williams' on 31.8.67.

The final assessment of dieback and regrowth was made on 24.6.68.

Experiment D. The effect of 2,4-D, MCPA and 2,4,5-T on plums.

The three herbicides were all used at rates of 0.017 and 0.05%. The treatments were applied on 21.7.67. Final growth measurements were taken on 24.6.68.

RESULTS

The development of injury symptoms in these experiments followed the same pattern as that already described (Ivens and Clay, 1966) and results are given only for the ultimate effect of the treatments on the shoots when assessed in the summer following treatment. This assessment indicated the likely maximum effect to be sustained from the treatments and is the most useful in comparing their phytotoxicity.

Experiment A.
The results of the final assessment are presented in Figure 1. There was a decrease in the degree of injury where the treatments were applied later in the season, the reduction being particularly noticeable at the September application. The pattern is the same regardless of the chemical or the variety, except in the case of Bramley. With the variety, Bramley, while the dieback caused by the September treatment is less, there is more extensive dormancy and development of formative effects on shoots emerging below the treated part. In some cases this effect spread to shoots emerging above and below the treated branch on the main stem. Apart from this effect on Bramley, the extent of the injury in apples was not great, only the treated shoot being affected. The toxicity of the chemicals was in the order 2,4,5-T > MCPA > 2,4-D. The initial effects of MCPA on shoots recorded in the season of treatment were generally less severe than 2,4-D. Susceptibility of the varieties was in order Bramley > Cox > Lord Lambourne and Worcester.

Experiment B.
The early effects of treatments in this experiment have been reported (Ivens and Clay, 1966). The results of the final assessment on Lord Lambourne are presented in Figure 2. They show the same pattern of effect as before, with 2,4,5-T, mecoprop and picloram causing the most injury. The last two herbicides, while not killing back the shoot extensively induced dormancy over the treated length. The butyric acid analogues were similar in degree of effect to the acetic acids, but, of course, had been applied at rather higher doses. There were no formative effects from any of these treatments on Lord Lambourne showing 1 or 2 years later. There was rather less difference between varieties in response to the different herbicides than in experiment A. but the order of susceptibility was the same.

Fig.1. Expt.A. The effect of 2,4-D, MCPA & 2,4,5-T applied to shoot tips.

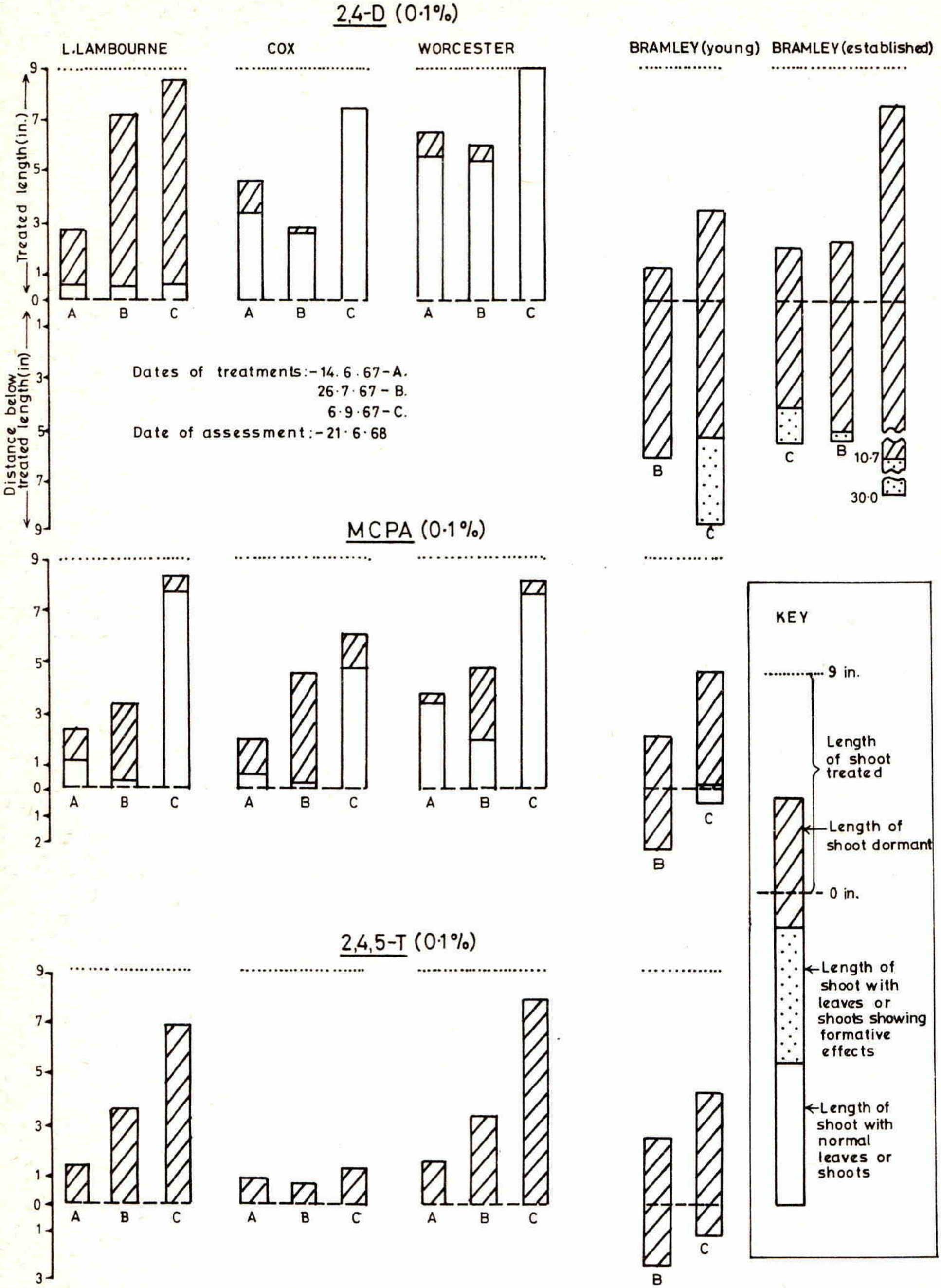
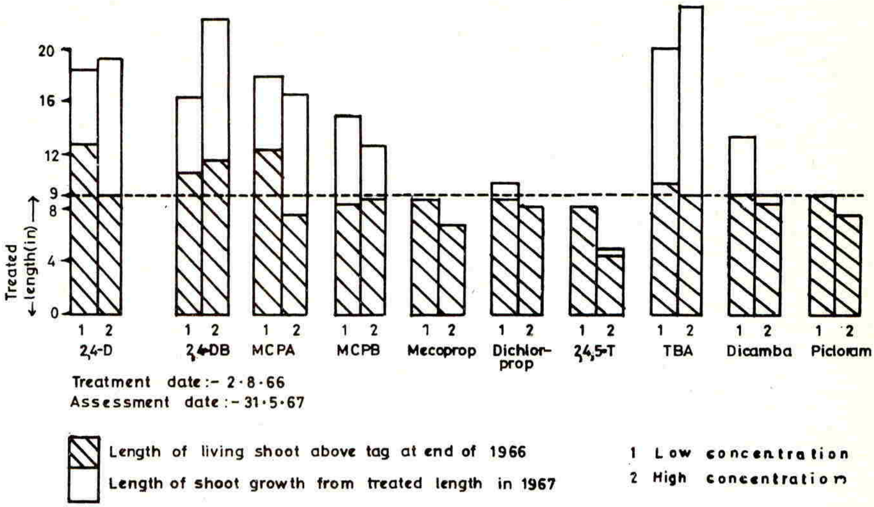


Fig. 2. Expt.B. The effect of a range of growth regulator herbicides on apple. var. Lord Lambourne.



Experiment C.

The effects of the herbicides applied to pears in July and August 1967 were recorded in June 1968 and these are shown in Figure 3. 2,4-D and 2,4-DB caused die-back and dormancy of the whole length of the treated shoot and produced serious formative effects the following year on shoots emerging up to twelve inches below the treated zone. Generally the severity and extent of the effects from the higher dose rates was greater than from the lower dose of the same herbicide particularly at the later application date. The type and extent of the effects of the other three chemicals were similar to those shown in apples. Differences in degree of effect were more marked at the earlier application date and were more noticeable on Williams' than on Conference. Mecoprop had almost no effect on Williams' at the later date of treatment apart from the death of the shoot apex.

Experiment D.

The final assessment of shoot dieback from treatments applied to plums in July 1967 is shown in Figure 4. The order of toxicity of the chemicals was 2,4,5-T > 2,4-D > MCPA. The lower dose of 2,4-D and both doses of 2,4,5-T prevented regrowth for a few inches below the treated shoot.

Fig 3 Expt C The effect of a range of growth regulators on shoot tips of two varieties of pears.

Date of treatment:- A. 21·7·67
B. 31·8·67

Date of assessment:- 24·6·67

Key to histogram as in fig.1.

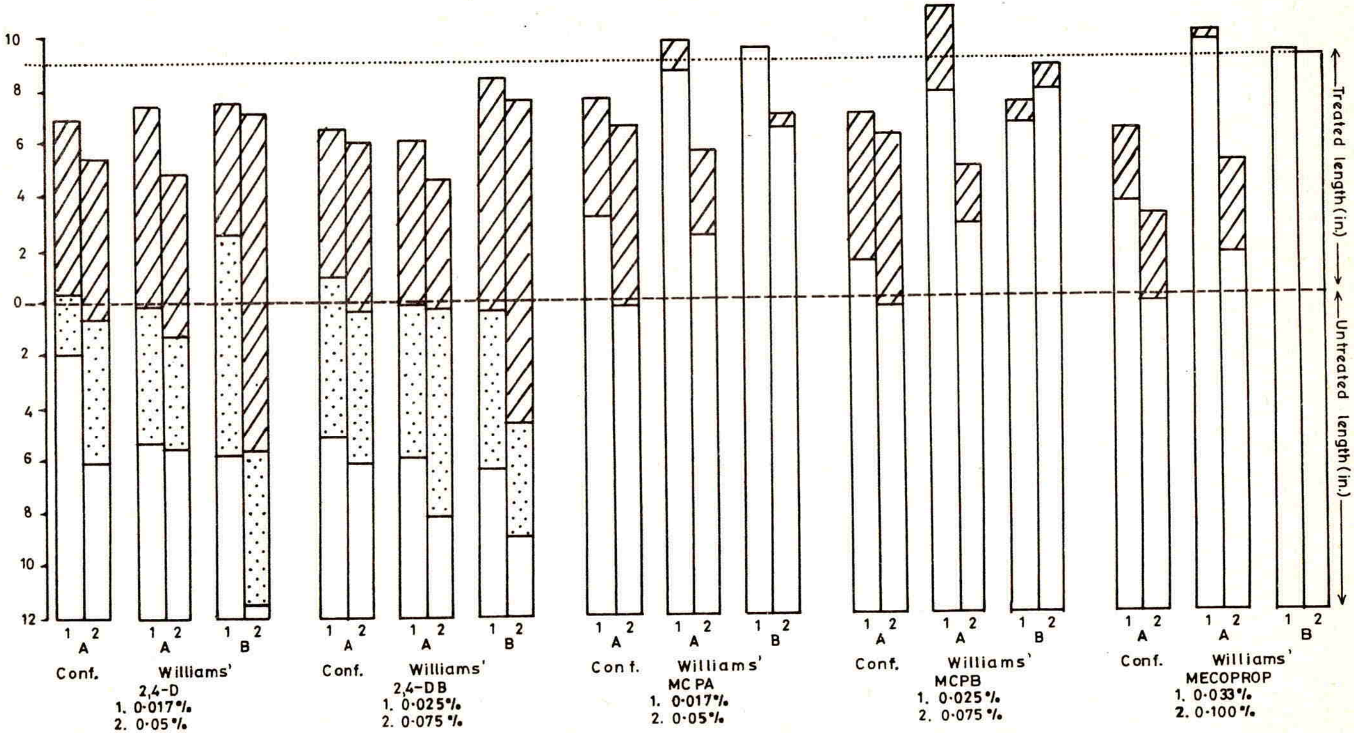
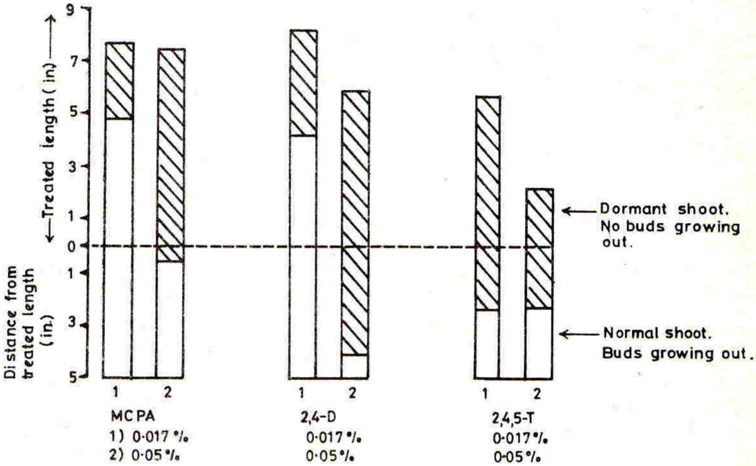


Fig.4. Expt. D. The effect of three growth regulator herbicides on plum shoots.

Date of treatment:- 21·7·67
Date of assessment:- 24·6·68



DISCUSSION

The experiment on the timing of treatment on apples confirms the impression gained in earlier experiments that the treatment of actively growing shoots causes more injury than when growth is slow or has ceased for the season (Ivens and Clay, 1966). This is also shown in work reported by Goddrie (1966) where mature trees of variety James Grieves sprayed overall with 0.4% 2,4-D in May, June and July, suffered serious stunting whereas trees treated in August were unaffected. However, the degree of difference obtained is not so great as to preclude careful use of growth-regulators in June and July. Similarly the effects of the different herbicides show that selection can be made on the basis of efficiency as a weed-killer rather than tolerance by the crop, the effects on the crop being restricted to the treated area. The action of 2,4-D on Bramley apples is the exception to this general pattern. Formative effects from shoot tip treatments were seen not only the year after treatment in branches arising from the main stem above and below the treated branch, but recurred on shoots growing out in 1967 from 1965 treatments. By analogy with the results in pears where much lower doses gave comparable effects to these, it is possible that small amounts of spray reaching the foliage in Bramley apples could cause serious injury in subsequent seasons. It can be concluded that 2,4-D, and probably 2,4-DB, are unsuitable for use in Bramley orchards where accurate spraying is likely to be difficult because of weather conditions, low growing foliage or unskilled operators.

The same general conclusions about the selection of suitable growth-regulator herbicides can be made as a result of the work on pears and plums. Although on balance these were more sensitive to the herbicides than apples, confirming the results of Luckwill and Campbell, (1957), they also generally showed only localised effects from the treatments. The results of a comparable experiment in pears carried out the previous year to experiment C, in which a higher dose level was used confirm this.

The differences in the response of the two varieties probably reflect the differences in growth rate. Conference, the slower growing variety was killed back less by the higher rates of MCPA, MCPB and mecoprop than was Williams', but most of the treated shoot remained dormant during the following season. There was little difference in the degree of effect of 2,4-D and 2,4-DB between the two varieties and between the two dose rates used. As in Bramley apples, this suggests that contamination of foliage with these materials in pears could produce serious effects the following seasons. Similarly, formative effects resulting from 2,4-D and 2,4-DB treatments in 1965 were still to be seen in shoots arising below the treated parts in 1967.

The degree of effect of the two dose rates used in the Williams' pears varied according to the time of application. Whereas the degree of dieback was markedly less from the lower dose at the earlier date, there was very little difference between doses at the later date. The length of shoot showing effects from 2,4-D treatments was, however, proportionately greater with the higher dose rates at both dates. The conclusion is therefore the same as in apples, that the growth-regulator herbicides can be used at all stages in the summer provided care is taken to avoid spraying onto the foliage but that the use of 2,4-D carries more risk especially when used late in the growing season.

Plums have been regarded as more susceptible to growth-regulator damage than are apples. (Luckwill and Campbell 1957). On the basis of this one experiment it appears that injury is intially more severe, but there was no indication of translocation of herbicides any appreciable distance down the shoot nor was there any carry over of effects into the subsequent year.

Acknowledgements

The trees used in this experiment were supplied by East Malling Research Station, whose help is gratefully acknowledged. Thanks are due to Mrs. J. A. Slater, J. I. Green, W. H. Bell and J. W. Heal for assistance in carrying out these experiments.

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PROGRESS REPORT ON WEED RESEARCH IN FRUIT CROPS IN THE NETHERLANDS

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Presented on behalf of the Subgroup Horticulture, Dutch Working Party for Weed Control.

FRUIT CROPS

Weed research in fruit crops is centered at the Experimental Station at Wilhelminadorp and supported by other members of the Group. Since 1963, the year in which aminotriazole and paraquat were introduced chemical weed control has become a general practice in orchards. In modern apple orchards with dense planting systems of 2,000 - 3,000 trees/hectare, the application of herbicides with specially constructed spray booms has been shown to be a safe, labour saving and easy technique. The number of officially approved products is increasing continuously.

The improved development and production of trees that has followed the use of herbicides is being ascribed to decreased competition from grasses and weeds. In experiments in Golden Delicious on M IX planted in 1958 on a sandy loam soil the root development of trees in plots kept weed-free with herbicides was compared with those in grassed-down plots. It was found that root development in the 0-30 cm soil layer in the tree rows (trees spaced 1 metre apart) was much more intense in plots treated with a variety of contact and soil acting herbicides than in those under grass culture. In particular the numbers of roots $< \frac{1}{2}$ mm and $\frac{1}{2}$ - 1 mm in size were much increased throughout the entire depth of rooting, which in this soil was about 1 metre. (van Staalduine 1968 b).

In another experiment with 14 year old apple trees growing on light clay soil, 4 years after introducing chemical weed control much improved rooting intensity was observed on the herbicide treated plots (van Staalduine, 1968 b). These observations are in agreement with data discussed at the 7th British Weed Control Conference (van der Zweep, van Staalduine and Goddrie, 1964). The consequences of improved shallow rooting within the tree row are only slowly being appreciated.

Early spring applications of paraquat or aminotriazole together with atrazine, diuron or simazine and followed in June/July by auxin herbicides are in common use. In 1964 the post-harvest use of aminotriazole was officially approved and the value of autumn applications of aminotriazole followed by spring paraquat has been confirmed, for by this means it is now possible to obtain weed-free conditions in the tree rows, an important consideration in areas where late spring frosts are prevalent and a layer of killed vegetation on the soil surface is not desirable. For the control of Polygonum amphibium, Symphytum officinale, Linaria vulgaris and some annual weeds which are not susceptible to an early spring application of paraquat and simazine the use of 2,4-D, MCPA and MCPP salts has received official approval. A mixture of MCPA and 75 g/ha dicamba is also allowed. The effect of these treatments appears to be considerably improved if they are followed at an interval of 1 - 2 weeks by an application of paraquat. In particular, treatment during the period end of July and early September has given good effect on Tussilago farfara, Rumex obtusifolius and Glechoma hederacea.

Pears are more susceptible than apples to auxin herbicides although treatments are officially approved. Observations in spring 1968 showed that treatments applied in summer 1967 caused growth symptoms; buds were killed and auxin like disturbances in flowers and leaves were apparent. The varieties Beurre Hardy, Beurre Alexander Lucas, Precose de Trevous and Conference appear especially susceptible. The occurrence of symptoms may have been influenced by the shallower root-systems which result from the practice of non-cultivation. Localized spot treatment may overcome the difficulty which has been encountered when overall row treatments have been used. The subject is under study in more detail at the moment.

Granular formulations of dichlobenil and chlorthiamid, have received official approval in apple orchards of 3 years and older. Use in younger orchards is under study. The occurrence of yelow leaf margins is more severe and occurs sooner after the use of chlorthiamid than of dichlobenil. Golden Delicious and Cox's Orange Pippin are more susceptible to this influence than other varieties e.g. Goldreinette. Soil type, dose applied, size of the tree and possibly rootstock are of importance in determining the severity of the symptoms.

Tussilago farfara, Cirsium spp., Taraxacum officinale, Rumex spp., and Equisetum arvense can be effectively controlled by spot treatments with chlorthiamid and dichlobenil. Polygonum amphibium can only be controlled prior to sprouting. Convolvulus arvensis is more susceptible to an April treatment than in July or August. Generally speaking growers are not well equipped for applying granular products.

Bromacil has received official approval in apple orchards that have been established for at least 3 years. Doses range from 0.8 - 2.4 kg/ha. For the control of perennial grasses 1.6 - 2.4 kg/ha is needed. Since 1966 bromacil and terbacil have been studied under young apple trees. Both products show selectivity at low doses in various varieties. Both appear to control a similar range of weeds both show slow initial activity, especially under dry conditions. The practical preference for one or other of the products cannot yet be indicated. Combinations of aminotriazole or paraquat with low rates of bromacil and terbacil (0.8 - 1.6 kg/ha) may offer good immediate and residual control of annual and perennial monocotyledonous weeds. The residual effect on annual weeds frequently considerably exceeds the effect of comparable rates of simazine and atrazine or of 6 kg/ha dichlobenil or chlorthiamid. Results of experiments are described more fully by van Staalduine (1968 a).

BUSH FRUITS

In one-year established plantations of red currants, black currants and gooseberries chlorthiamid and dichlobenil are presently recommended for the control of annual and perennial weeds.

Couch grass can be controlled by repeated applications of paraquat and/or post-harvest use of aminotriazole. Post-harvest use of MCPA has been approved for the control of Convolvulus and Calystegia.

In Vaccinium corymbosum experiments with bromacil and terbacil at 1.6 kg/ha gave good control of couch grass and other weeds, without damaging 2 and 4 year old plants growing on a highly organic type of reclaimed peat soil. Repeated applications in 1967 and 1968 did not cause undesirable effects either. April applications of a mixture of aminotriazole and bromacil, the latter at 0.8 kg/ha are very promising. The addition of aminotriazole to the uracils is desirable for more rapid initial action. These treatments gave results much superior to normal applications of atrazine, diuron, dalapon and paraquat. The recommendation awaits official approval of the Committee for Phytopharmacy.

STRAWBERRIES

In 1967 lenacil received official approval for use in strawberries at doses of 1.2 - 2 kg/ha. It is particularly valuable for use shortly after transplanting in August or early spring when it is more effective against young weeds, and cheaper than chloroxuron. Although lenacil seems to be safe on the crop when applied at any time, undesirable accumulation in the soil is prevented by maintaining an interval of at least 6 months between applications and by not applying the herbicide in the year in which the crop will be removed. Lenacil can also be used in propagation beds after transplanting and during runner formation, with the condition that the plants will not be removed before the following spring.

In older, established crops of strawberries there is no advantage in using lenacil instead of simazine, although in this case due consideration must be given to soil type, crop health and stage of growth.

Several years experience on various soil types has established that the control of weeds with herbicides and without cultivations is capable of maintaining good development of the crop. Runners and young rooted plants in the rows can be effectively removed by paraquat.

With the introduction of large fruited strawberry varieties such as Gorella, it has become possible to maintain the fields for more than 2 years. For this reason interest has recently increased in the chemical control of couch grass which is an increasing problem in sandy soils with good organic matter content, frequently leading to early removal of the crop. The use of bromacil and terbacil for couch control in older crops is under study (van Staalduine, 1968 a). Doses of 0.8 - 1.6 kg/ha bromacil and terbacil applied early in spring or July/August after harvest are promising. Heavy leaf damage has been caused during periods of rapid growth (May). Initially the activity of both products may be very slow due to dry weather conditions and consequently a post-harvest application seems preferable. After a summer application the effects on couch and other weeds are clearly recognisable until after the following harvest. At rates of 0.5 kg/ha annual weeds are well controlled and at 0.8 kg/ha post-emergence control is possible. The persistence of uracil herbicides in the soil requires critical consideration before their use can be recommended because of the susceptibility of following crops.

There is little experience with one-year old crops. Younger plants are definitely less tolerant than older ones and the possibility of varietal differences in susceptibility and the importance of soil type requires more study.

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SOME EFFECTS OF ASULAM AND α-CHLORO-6-t-BUTYL-o-ACETOTOLUIDIDE ON APPLE AND PLUM

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Summary Two herbicides of promise for the control of perennial weeds, asulam for Rumex spp. and α-chloro-6-t-butyl-o-acetotoluidide (CP 31675) for Agropyron repens, each at three rates, were incorporated into the soil before, or applied to the soil surface after, potting apple and plum rootstocks. The resulting shoot growth was measured monthly.

A reduction in growth, increasing with rate of application and with incorporation, followed CP 31675 applications, the plums being more severely damaged than the apples. It is concluded that the tolerance of plum and apple to CP 31675 is not such as to encourage its development.

Asulam increased the growth of the plums when incorporated at 4.5 lb/ac but no effect was detected on apple growth.

INTRODUCTION

Various perennial weeds remain difficult to control in orchards. At the 1966 Weed Control Conference a recently-developed herbicide, α-chloro-6-t-butyl-o-acetotoluidide (CP 31675) was reported to have a high degree of activity against one of the commonest of these weeds, Agropyron repens (Holly et al. 1966). It was therefore decided to find out if apple and plum have a high level of resistance to this herbicide. Docks, Rumex spp., are another problem weed. The herbicide asulam has been reported to give good control of docks in pasture and orchards (Ford and Combellack, 1966) and has been marketed for this purpose during 1968.

METHOD AND MATERIALS

The test plants were 168 one-year rooted layers each of the apple rootstock M.26 and the plum rootstock St. Julien A. The herbicides, each as a 75% w.p., were applied in February whilst the stocks were dormant, being either thoroughly mixed with the compost of loam and sand before planting or applied to the surface after planting in order to find out if any selectivity depended on the herbicides not reaching the tree roots. The herbicides were applied with a Van der Weij field plot sprayer in 100 gal. of water per acre, CP 31675 at rates of 0, 0.75, 1.5 and 3.0 lb/ac and asulam at rates of 0, 2.25, 4.5 and 9.0 lb/ac. The plants were potted in 5-in. plastic pots and were set out in a plunging ground in the open, there being 12 replicates of each treatment. Only one shoot was allowed to develop on each plant and its length was measured monthly.

RESULTS

CP 31675

The mean shoot lengths at the end of the season after treatment with CP 31675 are shown in Table 1.

Table 1

Shoot length (cm. per plant) after CP 31675 treatment

	Apple		Plum	
Rate lb/ac	Surface	Incorporated	Surface	Incorporated
0	45.8		56.2	
0.75	39.7	34.2	53.6	19.3
1.5	32.0	18.0	24.8	3.0
3.0	33.1	12.0	9.4	1.7
L.S.D. (5%)	10.14		13.74	

Only with the lowest rate of 0.75 lb/ac applied to the surface did growth approach that of the control plants; higher rates and incorporation of CP 31675 reduced the growth both of apples and plums. Although 3.0 lb/ac when incorporated reduced the growth of the apples to 26% of that of the controls, none of these plants died. Plums were more severely damaged, eight of the twelve plants with 1.5 lb/ac incorporated in the soil dying before the end of August. Graphs showing the growth of the apple shoots through the season are presented in Fig. 1.

Asulam

The mean shoot lengths at the end of the season after treatment with asulam are shown in Table 2.

Table 2

Shoot length (cm. per plant) after asulam treatment

	Apple		Plum	
Rate lb/ac	Surface	Incorporated	Surface	Incorporated
0	47.7		48.2	
2.25	52.4	45.5	55.5	54.8
4.5	53.1	47.7	48.2	68.9
9.0	45.2	47.0	51.0	49.1
L.S.D. (5%)	10.14		13.74	

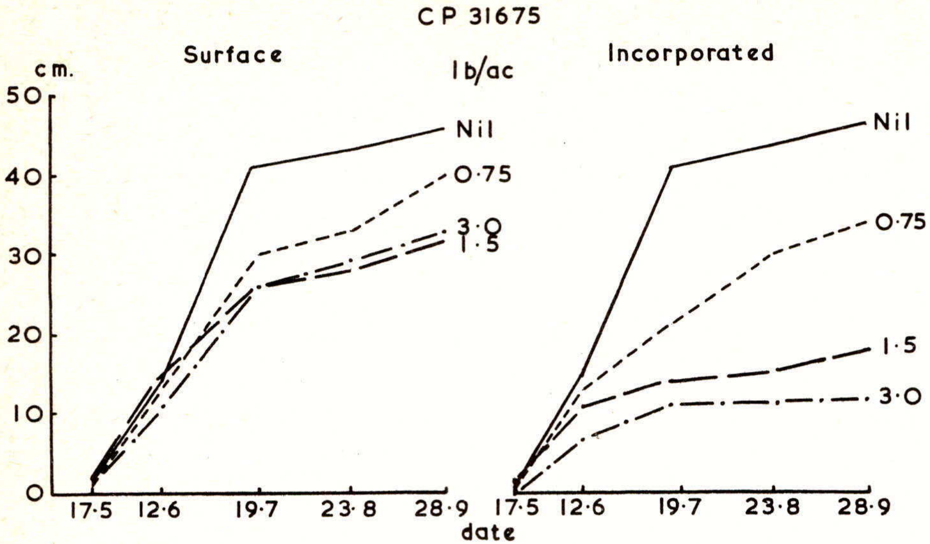

Fig. 1 Effect of CP 31675 on apple shoot length through the season.

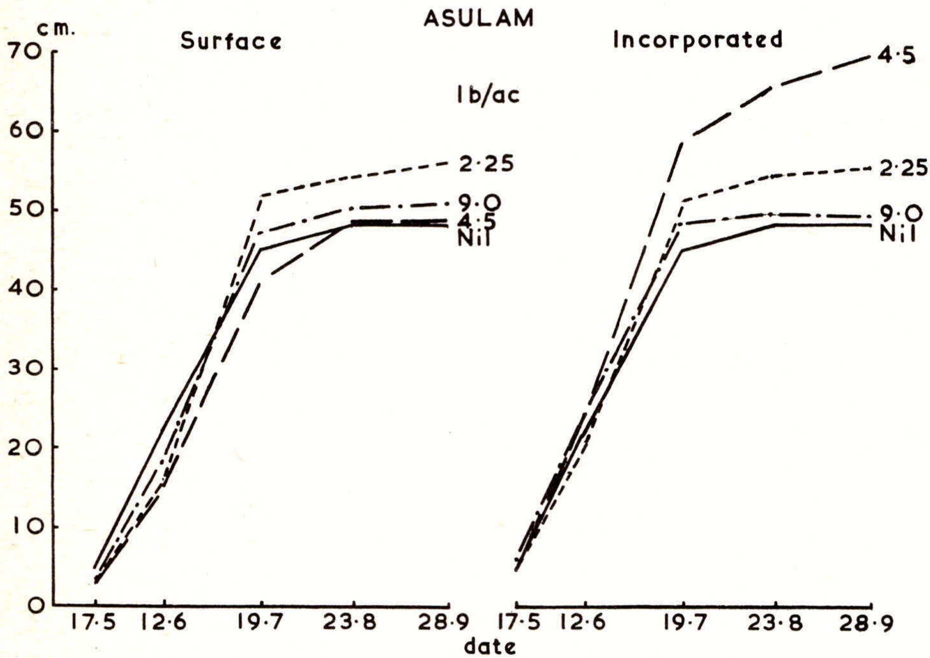

Fig. 2 Effect of asulam on plum shoot length through the season.

Asulam incorporated at 4.5 lb/ac increased plum shoot length by 43% compared with that of the control plants, none of the treatments on the plums producing growth less than that of the control plants. However, no effect was detected on the growth of the apple shoots. Graphs showing the growth of the plum shoots through the season are presented in Fig. 2.

DISCUSSION

These two herbicides have had differing effects on the fruit plants.

The reduction in growth of plum and apple caused by CP 31675 increased at higher rates of application and following incorporation. The lengths of the plum shoots when first measurable, in mid-May, already showed a severe check from the most damaging treatments which also markedly checked growth during June-July when the control plants were growing most rapidly. When the growth of the untreated plums slowed down in July-August the plants in the less severely damaging treatments grew faster, indicating that the herbicide may have ceased to have a direct effect at this time. Even though the plums which had CP 31675 applied to the soil surface at 1.5 lb/ac then continued growing until the end of the season they remained less than half the size of the control plants.

On the apples the reduction in growth rate caused by CP 31675 was less marked but continued from the commencement of growth until the end of August, when some of the treated plants started to grow more rapidly than the controls for the last month of the growing season, again indicating that the herbicide may have ceased to exert a direct effect by the end of August.

In this trial only a single application of the herbicide was made, but Holly et al. (1966) have shown that the growth of couch grass is suppressed only whilst the active herbicide remains in the soil. Furthermore they showed that incorporation was necessary for the best control of couch grass. Although the damage was less on apple than on plum, as shown by the smaller reduction in growth and absence of killing of the former, it is evident that neither crop plant is sufficiently tolerant of CP 31675 to encourage development of this herbicide.

The asulam-treated plums in general grew faster than the control plants during the period of most rapid growth in June-July. The growth of the plums which had asulam incorporated at 4.5 lb/ac continued at a greater rate than that of the control plants until at the end of the growing season they were 43% larger. This marked stimulation of growth is supported by apparent small increases in growth following the other asulam treatments. In contrast to this stimulation of the growth of St. Julien A by asulam no effect was detected on the growth of M.26 apple.

Thus the stimulation of plum growth following asulam treatment was most marked when the asulam was incorporated in the soil. This could be due to an effect in the soil or within the plant, but as a carbamate asulam would be expected to interfere with the processes of cell division and elongation. Further investigation is necessary to show how this interesting and unusual stimulation is brought about.

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PROGRESS REPORT ON WEED RESEARCH IN BULB CROPS AND ORNAMENTALS IN THE NETHERLANDS

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Presented on behalf of the Subgroup Horticulture, Dutch Working Party for Weed Control.

BULB CROPS

In the Netherlands the main centre of weed research in bulb crops is the Laboratory for Bulb Research at Lisse.

The demand for chemical weed control in bulb crops is increasing due to mechanisation of flower head removal on tulips and the mechanical harvesting of bulb crops in general. The long established use of chlorpropham does not result in sufficiently broad and extended weed control. Recently newer products have offered promising results in the control of annual weeds but perennial weeds can only be controlled before planting. Aminotriazole at 4.5 kg/ha, often in combination with 2,4-D at 1 kg/ha, is applied up to 6 weeks prior to planting but not later than about September 15th. The effect on couch grass is noticeable until the harvest period. Aminotriazole is presently used to a greater extent than paraquat and diquat due to its good effect on annual weeds as well.

Tulips and iris are cultivated on various soil types ranging from organic matter deficient sands to clays. In both crops a proprietary mixture of pyrazon and chlorbufam is recommended, except on soils with less than 1½% organic matter. The product is applied at the moment of crop emergence. Pyrazon at 1.6 - 2 kg/ha is only recommended on soils with more than 20% clay and 2% organic matter.

In weedy fields pre-emergence treatment with paraquat or paraquat + diquat or chlorpropham in autumn or early winter precedes the recommended treatment.

Hyacinths are only grown on sandy soils. Chlorpropham is applied in autumn and on fertile red sandy soil linuron at 0.75 kg/ha can be used pre-emergence. At emergence chlorpropham is used and on crops of larger bulb size than 9 cm pyrazon at 1 - 1.3 kg/ha is recommended one week after the previous treatment.

In narcissus pre-emergence weed control is required and this can be done with paraquat or combinations of chlorpropham with a paraquat + diquat mixture. For this treatment the protective straw cover is not removed.

Some days after the removal of the winter cover either the pyrazon + chlorbufam mixture or chlorpropham alone is applied to be followed, if desired, by a pyrazon treatment one week later.

Linuron is no longer recommended because of the risk of damage to the crop.

Since 1965 good results have been obtained on a limited scale with a technique in which winter rye at 250 - 300 kg/ha is sown over the narcissus beds immediately after planting in September. By December the rye crop is about 20 cm high and before emergence of the narcissus, the cover is killed with a paraquat + diquat mixture. Decay proceeds very slowly and the mulch thus created persists into spring preventing wind-blow of the soil and damage to the plants. This new method results in a considerable saving in labour and expense compared with the traditional use of straw covers. A general recommendation for the technique is not possible until it has been established that in severe winters the protection given by the rye cover is sufficient.

In anemones linuron at 0.75 kg/ha is recommended on good sandy soils and at planting depths of at least 5 cm. As yet insufficient experience has been obtained on soils poor in organic matter.

In gladioli a distinction is being made between gladioli grown from cormels and those grown from flowering size corms. In cormels only chlorpropham and paraquat is recommended. Chloroxuron has given good experimental results. In crops grown from corms the doses are related to soil type. Officially approved uses are linuron at 0.71 - 1 kg/ha, if necessary in combination with paraquat or dinoseb-acetate + monolinuron in a commercial formulation. It is necessary to plant at least 5 cm deep. In soils very poor in organic matter the application of these products is not recommended.

During the last few years much research attention has been devoted to lenacil. In tulips effects on the crop in early spring trials were variable. On sandy soils rates of 0.8 kg/ha appeared too high but on medium loam and clay soils the treatment has possibilities.

In hyacinth a physiological tolerance to lenacil has been established. Also in narcissus, iris, lilies, anemones, muscaris and Scilla siberica good results have been obtained when lenacil was applied at crop emergence. In gladioli the use of lenacil is too risky.

Practical recommendations for lenacil are not possible until the extent of residues in the soil at harvest has been established. The matter is being further pursued.

FLOWER CROPS

An increasing interest in herbicides is apparent in outdoor as well as glass-house flower crop growing. Municipal park authorities and private gardeners also frequently consult the relevant Experimental Stations (at Aalsmeer and Naaldwyk), Advisory Services and herbicide experts.

Official approval has been given for practical recommendations in a series of crops for 1968.

For pre-emergence application the use of contact herbicides is being emphasised. In Freesia dimexan or EXD is preferred to paraquat. The use of soil-acting herbicides is approved officially for the following products in the indicated crops: propachlor in Iberis umbellata and Hesperis matronalis; linuron in Centaurea cyanus, Tropaeolum majus, Reseda odorata and Linum perenne; chlorpropham in Campanula media. Promising experimental results have been obtained in Chrysanthemum maximum with chlorpropham, propachlor and the proprietary combination of cycluron and chlorbufam. Propham and chlorpropham are promising in Tagetes and lenacil in Viola tricolor.

Post-emergence or post-planting applications must preferably be carried out on plants with 3 or more true leaves; in general in younger crops the risk of growth retardation increases. In crops growing under glass for safety reasons treatment is usually carried out during late afternoon using high volumes, while next morning the plants are thoroughly watered. This technique also improves the residual action of the herbicide.

For chloroxuron the following recommendations have received official approval. Post-planting treatments in Chrysanthemum morifolium (outdoors and under glass), Pyrethrum roseum, Dianthus barbatus (only in open field), Dianthus caryophyllus (outdoors and under glass). In taller crops, especially Dianthus applications can be made under the crop-foliage. Insufficient experience is as yet available for use in rooted cuttings, directly transplanted from the mother bed. In Viola tricolor post-emergence and post-planting treatments may cause growth reduction on small plants. With chloroxuron good results have been obtained with Papaver nudicaule (post-emergence after growth commences in spring), Campanula persicifolia (post-planting and after growth commences in spring).

Propachlor is officially recommended for post-transplanting treatments in Pyrethrum roseum, Dianthus caryophyllus (open field only) and Viola tricolor. Good experimental results have been obtained in Dianthus barbatus, and Campanula persicifolia (post-transplanting applications in autumn and after start of regrowth in spring). In Myosotis alpestris, Cheiranthus cheiri and Papaver nudicaule applications after start of regrowth in spring are promising.

Post-transplanting applications in spring were tolerated by Ageratum mexicanum, Aster spp. Dahlia pinnata, Alyssum spp. Antirrhinum majus, Petunia, Lobelia Erinus and Verbena chameadrifolia.

Asulam is another promising herbicide for spring applications after growth commences in Papaver nudicaule and Myosotis alpestris.

Myosotis alpestris has been shown to tolerate overhead applications of paraquat at 0.6 kg/ha in autumn. In Viola grown for seed production the use of this technique.

NURSERY CROPS

Paraquat has almost entirely replaced other contact herbicides and selective aromatic oils for pre-emergence use in seed-beds. Soil-acting herbicides are hardly recommended except in some large seeded hardwood crops such as Castanea, Corylus, Juglans and Quercus where simazine is being used at 0.75 kg/ha.

Soil fumigation is practised to an increasing extent. The products methyl-dibromide, metham sodium and a mixture of DD and metham-sodium also have good herbicidal activity.

In established perennial crops simazine is used on a large scale at doses of 0.375 - 1.5 kg/ha, the dose depending on age of crop and soil type. Repeated treatment takes place in September/October in order to prevent weed growth in winter.

In hardwood crops which are susceptible to simazine after budding in spring a 2% granular formulation is being used at the same active dose.

In hardwood nurseries November/December applications of either chlorpropham (1.6 kg/ha) or a combination of chlorpropham and DNOC are still used although on a smaller scale than before. In crops with sufficiently lignified branches and stems paraquat and PCP-oil-emulsions are used. Paraquat may however cause rubbery wood-like symptoms in young apple trees if the spray thoroughly wets the branches during summer applications. The symptoms of damage are discolouration of the wood at the treated area and the branches bend intensely. Overall sprays carried out in autumn or early spring did not cause these effects.

In roses, after heading back the stocks in early spring a mixture of paraquat and simazine can be applied as an overall spray. Experimental and practical experience has demonstrated the possibilities in this crop of bromacil and terbacil.

In 1967 the effects of granular formulations of chlorthiamid and atrazine applied shortly after transplanting to a range of one and two year old hardwood species was studied. On organic peat soils at Boskoop chlorthiamid caused damage at 5.25 kg/ha in several crops.

Due to the very wide range of crops and varieties much more research is needed, especially with chlorthiamid and dichlobenil, before applications can be officially approved. Low rates of dichlobenil are being studied for the control of annual weeds in young transplanted shrubs and trees in parks and along roads.

In one year established plantations granular formulations of chlorthiamid have been officially approved for use for a few crops. The granular dichlobenil formulation has been officially approved at 4 - 5.4 kg/ha in two year established plantings, with the exception of Potentilla, Sambucus, Rhamnus and Coniferous species. In practice both products are being used on a large scale.

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WEED CONTROL IN BULBS: A SUMMARY OF WORK AT KIRTON

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Summary A wide range of herbicides applied to tulip and narcissus over the last fifteen years is listed with brief notes on their effect on bulbs and weed control.

INTRODUCTION

During the last fifteen years a wide range of herbicides has been used on narcissus and tulip at Kirton Experimental Horticulture Station. The following tables are a brief summary of the results obtained. Detailed results of some of the replicated experiments have been reported in previous issues of the Proceedings of the British Weed Control Conference from 1956 onwards, and herbicides used in these experiments are included in this paper.

The soil at Kirton E.H.S. experimental bulb plots is classified as a very fine sandy loam. It is well drained, but tends to cap on the surface after heavy rain.

Weed growth varies with the soil condition and season, as do the predominant weeds. After a cold dry winter and spring, weed growth may not become vigorous until May, while in a mild wet winter, weeds may begin to grow vigorously in early spring. Where herbicides have been used for several years, an average weed control is given in the summary, but where a herbicide has only been used for one year, the results obtained in that year are given.

For the sake of clarity the list has been divided into different tables. Pre and post crop emergence applications are listed separately because a herbicide may be completely safe pre-emergence and cause severe damage post-emergence. The herbicides have also been divided into those used in fully replicated experiments, where yield results are reliable under the soil conditions at Kirton E.H.S., and those which have only been used in preliminary investigations on single plots, where yields may not be reliable. Most herbicides are used for at least a year on single plots before inclusion in a replicated experiment and unless the rates of herbicide used differ, only the results for the replicated experiment have been included in the lists. Where residual herbicides have been used after the application of a contact spray this has not been listed separately, although the weed control may have been improved by application to clean soil.

METHOD AND MATERIALS

All herbicides are applied in 100 gal/ac water, using an Oxford Precision Sprayer. Bulbs are grown for one year in flat beds, the plot size and bulb number having changed over the years from 50 bulbs in a Dutch bed, to 200 bulbs ploughed into a bed 8 ft long by 3 ft 9 in wide.

Mixtures of cycluron/chlorbufam, pyrazon/chlorbufam and linuron/monolinuron were commercial products, but all other mixtures of herbicides used have been made up at Kirton E.H.S. The commercial products used for the purpose were compatible

Key to tables

N = narcissus   T = tulip

Weed Control.
P = Poor, broke down by end of April
F = Fair, broke down by end of May
FG = Fairly good, broke down early June
G = Good, broke down mid June
VG = Very good, only a few weeds at the end of June

Weed control is omitted in the tables of post emergence applications because the effect of the herbicide often depends on the size of the weed at the time of the application, and these applications were given at particular stages of bulb growth.

*Indicates applications to kill bulb leaves just before or at senescence.

Where experimental results with herbicides have been reported in detail in previous Proceedings of the British Weed Control Conference the numbers in brackets under the column heading Weed Control give the reference

Table 1

Pre-emergence winter applications in replicated experiments

Herbicide	Rate a.i. lb/ac	No: years used N	T	Effect on bulbs	Weed Control
chloroxuron	4.5	1	1	No effect	F. (6)
chlorpropham	3,4,8	4	4	Yield reduction at 8 N and T	FG at 4 and 8 (1,2,3,4)
difenoxuron	4	2	2	No effect	F (6)
dimexan	8	1	1	No effect	contact only (5)
dinoseb (amm)	8	4	4	Slight damage 1 year N and T	F (1,2)
DNOC	12	4	4	Yield reduction 2 years T Yield reduction 1 year N	F (2)
diquat	2	2	2	No effect	Contact only (5)
diuron	0.4,0.4+0.4	1	1	No effect	P. Veronicas grew (4)
lenacil	2,3,4	2	2	No effect	F at 2,3, FG at 4
lenacil	6	1	1	Slight yield reduction T	G
linuron	1,2	3	3	No effect	G at 1, VG at 2 (6)
monuron	4	3	3	Yield reduction and leaf damage N and T	(1)
PCP	6,7.5,10.5	4	4	No effect	P at 6 (2)
PCP	16			" "	G at 16 (1)
prometryne	1.5,3	1	1	" "	F at 1.5, FG at 3
prometryne	4	4	2	Slight yield reduction T	G/VG (6)
pyrazon	4	1	1	No effect	G except for chickweed (6)
simazine	0.5,1	2	2	Yield reduction N and T at 1	VG at 1 (3,4)

Table 1 (Contd.)

Herbicide	Rate a.i. lb/ac	No: years used N	T	Effect on bulbs	Weed Control
TCA	10,20	2	2	Yield reduction N and T, flowers damaged following year N	(1)
chlorpropham+ chloroxuron	2+2	2	2	No effect	F/FG (4,6)
chlorpropham+ chloroxuron	2+0.5	1	1	" "	F (6)
chlorpropham+dimexan	2,3+8	1	1	" "	F/FG (5)
chlorpropham+ dinoseb (amm)	2+ 3	3	3	" "	FG/G (5)
chlorpropham+ dinoseb (oil)	2+ 3	1	1	" "	FG/G (5)
chlorpropham+diquat	2+2	3	3	" "	F/FG (5)
chlorpropham+diuron	2+0.4	6	6	" "	FG/G (4,6)
" "	2+0.8	3	3	" "	FG/G (6)
" "	2+0.4 twice	2	2	Slight leaf damage and yield reduction on T	VG (4)
" "	2+0.8 twice	1	1	Tendency to yield reduction N and T	VG (4)
chlorpropham+fenuron	2+0.5	2	2	No effect	FG (3,4)
chlorpropham+lenacil	2+0.5	-	1	" "	FG
chlorpropham+linuron	2+0.5	2	2	" "	G (6)
" "	2+1	1	1	" "	VG (6)
chlorpropham+neburon	2+0.5	2	2	" "	F/G variable (4)
chlorpropham+paraquat	2+2	2	2	" "	FG (5)
chlorpropham+PCP	2+6	2	2	" "	G (5)
chlorpropham+propanil	2+1.66	2	2	" "	FG (5,6)
chlorpropham+simazine	2+0.5	2	2	" "	G/VG (4)
cycluron/chlorbufam	1.14	2	2	" "	F
cycluron/chlorbufam+ chlorpropham	1.14+ 2	1	1	" "	FG (5,6)
linuron+monolinuron	1.4+0.6	1	1	Slight leaf and yield damage on T	G
pyrazon+lenacil	4+2	1	1	No effect	VG
pyrazon/chlorbufam	3.6,4,6	4	4	" "	G at 4, VG at 6 (6)
" "	9	-	1	Yield reduction	VG
pyrazon/chlorbufam+ propachlor	4+ 4	1	1	No effect	VG

Table 2

Pre-emergence winter applications. Single plot treatments

Herbicide	Rate a.i. lb/ac	No: years used N	T	Effect on bulbs	Weed Control
aminotriazole	1,2	1	-	May have reduced yield at 2	
atrazine	1	1	1	Severe damage N and T	FG
bromacil	0.5,1	1	1	Good bulb killer N and T	
chloramben	1,2	1	1	Possible yield reduction at 2 on T	F at 2
dacthal	2,4,6,8	1	1	No effect	FG at 6,8
dalapon	5,10	2	-	Slight flower damage at 5	
desmetryne	0.25,0.5	3	3	No effect	P at 4
"	1,2,4			" "	
dicryl	2,4,6,8	1	1	" "	FG at 6,8
diquat dichloride	1.5	1	1	" "	Contact only
endothal	4,5	1	1	Some visual damage N and T	P
EPTC	4	-	1	Severe damage. Mixed in soil just before planting	
ioxynil	1	1	1	No effect	P contact only
monolinuron	1,2	1	1	" "	F at 1, FG at 2
pentanchlor	1,2,3	1	1	" "	P all rates
"	4	-	1	" "	F
prometon	2,3,4,6	1	1	Severe damage N and T all rates	G above 2
propachlor	5,7	1	1	No effect	F
propazine	0.5,1	1	1	Severe damage at 1.5 on T and 3 on N	
"	1.5,3				
simetryne	1,2,4	2	2	No obvious damage	F at 1, FG at 4
trifluralin	1,2	1	1	Possible yield reduction on T at 2	VG
terbacil	0.5,0.75	1	1	Severe yield reduction on T at 0.75. No effect N	VG
chlorpropham+chloramben	2+1	1	1	No effect	FG
chlorpropham+2,4-DES	2+2,4	1	1	Some visual damage N and T	G
chlorpropham+endothal	2+4,6	1	1	Some visual damage N and T	G
chlorpropham+propanil	2+3.3	1	1	No effect	FG
chlorpropham+pyrazon	2+2	2	2	" "	G
linuron+diuron	1+0.4	1	1	" "	G
pyrazon/chlorbufam	9,12	1	1	Yield reduction N and T both rates	VG
pyrazon/chlorbufam+ lenacil	4,6+2	1	1	No effect	VG both rates
pyrazon/chlorbufam+ linuron	4+0.5	1	1	" "	VG
pyrazon+lenacil	4+0.5	1	-	" "	VG
pyrazon+linuron	4+0.5	1	1	" "	VG

Table 3

Post-emergence applications on replicated experiments

Herbicide	Rate a.i. lb/ac	No: years used N	T	Time of application	Remarks
chlorpropham	4+4	1	1	4 in winter+4 in March	Yield reduction T
"	2+2	3	3	2 in winter+2 at various stages of growth	(4)
"	2	2	2	At 4 stages of growth	(3)
chlorpropham+diuron	2+0.8	3	3	T furled leaf. N 3-4 in.	No damage (6)
chlorpropham+linuron	2+0.5	2	2	" " " "	" " (6)
" "	2+1	1	1	" " " "	Leaf damage and yield reduction T (6)
chlorpropham+propanil	2+1.6	1	1	" " " "	(6)
chlorpropham+cycluron/ chlorbufam	2+ 1.4	2	2	" " " "	(6)
lenacil	2	1	1	" " " "	No damage
"	2	1	1	After flowering	Probably safe
linuron	0.5,1	2	2	T furled leaf. N 3-4 in.	Leaf damage and yield reduction at 1 on T
"	0.5	1	1	Just before or after flowering	Yield reduction T. N before flowering only
linuron/monolinuron	1	1	1	T furled leaf N 3-4 in.	Leaf damage and yield reduction T
pyrazon	2,4	2	2	T furled leaf.N 3-4 in.	No damage
pyrazon/chlorbufam	2,4	2	2	" " " "	" "
" "	2,4	1	1	Just before or after flowering	Yield reduction T 2 and 4 before flower, 4 after flowering. N no damage

Table 4

Post-emergence applications. Single plot treatments

Herbicide	Rate a.i. lb/ac	No: years used N	T	Time of application	Remarks
atrazine	0.5,1,2	1	1	23 March	Severe leaf and bulb damage at 0.5 N and T
chloroxuron	4.5	1	1	13 March	Some leaf damage N and T
chlorpropham	8,16	1	1	March	Leaf damage N and T
chlorpropham+propanil	2+3.3	1	1	March	No damage
desmetryne	0.25,0.5	1	1	8 February	" "
"	1	1	1	" "	" "
2,4-DES	2,4,8	1	1	9 March, 20 April	Leaf and flower damage 4, 8 N and T
di-allate	1.5	1	1	20 February	Leaf damage N and T
dimexan	8	1	1	*11 July	Good leaf kill but slow. No bulb damage

Table 4 (Contd.)

Herbicide	Rate a.i. lb/ac	No: years used N	T	Time of application	Remarks
dinoseb	1.8	2	2	*16, 23 June	Good leaf kill. No bulb damage
diquat	2	2	1	*16 and 23 June	Severe bulb damage T. No obvious damage N
diuron	0.5,2	1	1	April. Full leaf	Leaf damage at 2 N and T
ioxynil	0.25,0.5	-	1	15 April	Leaf damage all rates
"	1	-	2	" "	" " " "
"	0.5	1	1	8 February)	No obvious damage
	0.75,1	1	-	10 March)	
morfamquat	0.6,0.8	1	1	10 March)	Leaf damage and yield reduction N and T all rates
	1.2	1	1	")	
monuron	0.5,1	1	1	23 March	Some leaf damage N and T
paraquat	1,2,3	2	2	*11 May, 16 June	Good bulb killer all rates N and T. June most effective
prometon	2,4,6	1	1	10 March	Good bulb killer at all rates
prometryne	0.5,1	1	-	2 April)	Severe damage all rates N and T
"	2,3,4	2	2	25 April)	
propachlor	4	1	1	8 February	No damage
TVO	80 gal.	1	1	*11 July	Good leaf kill. No bulb damage

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