HERBICIDES FOR EARLY PLANTED STRAWBERRIES

Hilary M. Hughes
National Agricultural Advisory Service
Efford Experimental Horticulture Station, Lymington, Hants

Summary Strawberries varieties Cambridge Favourite and Cambridge Rival planted August or September 1962 on a gravel loam in a replicated experiment showed significant crop reduction where simazine (1 lb/ac a.i.) was applied within a few days of planting. Similar applications two or three weeks after planting caused less crop reduction. Cambridge Favourite was more damaged than Cambridge Rival and August runners more than those planted in September. In 1963 four varieties were sprayed with chloroxuron (5 lb/ac a.i.) immediately after planting in August or September, and reasonable weed freedom maintained until spring by simazine ($\frac{1}{2}$ lb/ac a.i.) applied in early December. Preliminary crop results 1964 show these plants yielded as well as hand hoed controls. Simazine (1 lb/ac a.i.) two or four weeks after planting, again produced some crop reductions. The two varieties responded similarly to the treatments in both years. August planted runners gave much heavier yields than September planted runners in both years. Polygonum aviculare (knotgrass) germinating in late winter and spring was not controlled by any treatment.

INTRODUCTION

In the specialist early production areas in the south and west in order to obtain early and heavy crops from one-year plants it is necessary to plant strawberry runners in August to September. Because of the warm soil, often irrigated to ensure good growth of the runners under warm conditions, weed growth can be rapid and immediate cleaning operations essential.

In response to requests from growers in Southern England a series of experiments was started at Efford in 1962 to investigate suitable herbicides for these early planted strawberries. It was also hoped that the information would be of value to growers of cloched strawberries which are usually planted about the same time.

The results of the first experiment cropped in 1963 have been reported elsewhere (Hughes and Ivens 1964). They showed that simazine was unlikely to be a safe herbicide for newly planted strawberries. The introduction of chloroxuron enabled this material to be tested in the second experiment and these results, together with those of 1963, are summarised here.

METHOD AND MATERIALS

1963 Experiment

Medium sized runners of Cambridge Rival and Cambridge Favourite were planted 9 in x $2\frac{1}{2}$ ft on 22 August and 20 September 1962. The plants were irrigated after planting. Each treatment plot consisted of three rows of Cambridge Rival and three rows of Cambridge Favourite and plots were separated by single guard rows and cross paths. Each recorded variety plot consisted of 45 plants. The design and layout devised by East Malling Research Station was a Latin Square with 8 replications and restricted randomisation to permit of evaluation of differential treatments to be applied for the second crop year.

1964 Experiment

Four varieties were included Cambridge Rival, Cambridge Favourite, Cambridge Vigour and Redgauntlet making a 12 row treatment plot. Design and other details were similar to the 1963 experiment and this experiment was planted on 22 August and 13 September 1963.

The experiments were planted adjacent to each other. The soil was a coarse gravelly loam, and mechanical analyses showed over 70 per cent coarse and fine sands and less than 30 per cent silt and clay. Both experiments had control plots which were hand and tractor hoed and which required two to three cultivations in the autumn and three cultivations in the spring. The experimental herbicides were applied by a knapsack sprayer with pressure regulator using a 4 ft boom with four L.V. 000 nozzles at the volume rate of 50 gal/ac. The plants were given normal good commercial management and the crop graded as picked into punnets. Waste fruit was also recorded.

RESULTS

1963 Experiment

There was a much heavier crop from runners planted in August than September, but the simazine applications caused more damage to the August plants. From Table 1 it will be seen that both varieties were severely damaged by simazine within a few days of planting and the damage was less the longer the interval between planting and herbicide application. Cambridge Favourite was more damaged than Cambridge Rival. On the September planting the damage was less and for Cambridge Rival was not significant, although with Cambridge Favourite all applications caused crop reduction.

Table 1

The effect of simazine (1 lb/ac a.i.) applied at different times after planting 1962 on the total yield of two strawberry varieties 1963 (cwt/ac)

Treatment	Planted 22 August 1962		Planted 20 September 1962	
	Cambridge Favourite	Cambridge Rival	Cambridge Favourite	Cambridge Rival
Untreated. Hoed.	198	143	122	68
6 days after planting	89	87	85	63
13 days after planting	130	111	100	72
22 days after planting	166	133	100	65

Simazine controlled all weeds with the exception of spring germinating knotgrass (Polygonum aviculare) which was dominant on all plots and was very lightly scraped off all plots by hand hoes before strawing down the plants in May. On the cultivated plots the main weeds were corn spurrey (Spergula arvensis), annual meadow grass (Poa annua), chickweed (Stellaria media), mayweed (Matricaria sp.) and knotgrass (Polygonum aviculare).

The simazine immediately after planting caused chlorosis of the leaves, particularly on Cambridge Favourite, stunting of plant growth and some death. Symptoms were similar but less severe the longer the interval between planting and herbicide application. During the spring the cultivated plants looked more vigorous than the herbicide treated plants, although this difference was least noticeable on the September planted Cambridge Rival.

1964 Experiment

The use of chloroxuron (5 lb/ac a.i.) 9 days after planting in August and 5 days after planting in September kept the plots nearly weed free until early November. Simazine ($\frac{1}{2}$ lb/ac a.i.) was then applied on 13 December to control all weed seedlings then present, mainly Polygonum aviculare in the first true leaf stage. The plots that had received simazine (1 lb/ac a.i.) two or four weeks after planting remained weed free during the autumn and winter. In April Polygonum aviculare germinated in great profusion on all plots but less on those treated with simazine on 13 December. This difference may have been due to the exceptional rainfall of November 1963 when 6.6 in. fell and which may have leached the simazine which was applied in September, but not that applied in December. The knotgrass covered all the ground, as in the 1963 experiment, and again had to be lightly scraped off, before strawing the plants. Knotgrass adjacent to strawberry plants had to be left but does not appear to have affected crop, but was difficult to remove when the plants were cleaned up, after burning off in August 1964, for the second crop.

The other weed species present were similar to those in the 1963 experiment. Isolated plants of Poa annua and other gramineae that became established were spot treated with paraquat.

Table 2 gives the total yields (unanalysed) of the four varieties planted slightly wider than the 1963 experiment, at 9 in x 3 ft.

Table 2

The effect of herbicides on the total yield (cwt/ac) of four varieties of strawberries 1964

Treatments	C. Favourite	C. Rival	C. Vigour	Redgauntlet
	Planted 22 August 1963			
Untreated. Hoed.	182	125	190	128
Chloroxuron 9 days after planting and simazine 13 December	185	124	195	135
Simazine 13 days after planting	143	112	182	109
Simazine 28 days after planting and one hoeing	159	121	160	105
	Planted 13 September 1963			
Untreated. Hoed.	66	37	57	43
Chloroxuron 5 days after planting and simazine 13 December	66	44	57	43
Simazine 12 days after planting	45	30	37	33
Simazine 31 days after planting and one hoeing	49	36	43	33

The effect of planting date on yield was even larger than in 1963, August plants far outyielding those planted in September probably because of the very wet autumn and winter of 1963/4.

The yields show that there was no reduction from the chloroxuron plus simazine treatment compared with hand hoed controls for both planting dates. As in the 1963 experiment simazine (1 lb/ac a.i.) within two weeks of planting always caused a marked crop reduction particularly with Cambridge Vigour planted in September and Cambridge Favourite in August, and Cambridge Rival was less affected.

Simazine (1 lb/ac a.i.) within two weeks of planting, or after the first hoeing, caused obvious plant growth damage, particularly on Redgauntlet and Cambridge Vigour, the plants appeared smaller and of a paler green colour compared with the hoed plants. There were no obvious simazine chlorosis symptoms on the leaves of any of the varieties.

DISCUSSION

Both experiments suggest that the use of simazine at the rate chosen for these experiments of 1 lb/ac a.i. after planting strawberries in August, and to a lesser extent in September cannot be safely recommended. Chloroxuron (5 lb/ac a.i.) appears safe if applied within a few days of planting in August or September and can keep the ground weed free for two to three months. By this time the plants are well established and also root growth is minimal. Simazine ($\frac{1}{2}$ lb/ac a.i.) could then safely be used in late November to early December and will kill small weed seedlings of susceptible species that have not been controlled by chloroxuron or may have germinated later. At this rate, however, simazine will not control spring germinating knotgrass. Other studies at Efford have indicated that simazine at 2 lb/ac a.i. applied in the early winter may control knotgrass but the detailed effect on the plants has not yet been tested. Further experiments are in hand to evolve a herbicide programme that will permit good growth and yield of maiden strawberries with no cultivation, using several applications of chloroxuron, or chloroxuron and simazine, at varying rates and combinations. Economically it may be well worth while to use a herbicide programme that eliminates all need for cultivation even if there is a slight reduction in crop.

REFERENCE

Hughes, Hilary M., and Ivens, G. W. Use of simazine on young strawberry plants. Exp. Hort. 12 (in the press).

WEED CONTROL IN STRAWBERRIES WITH CHLOROXURON

J.G. Davison
Agricultural Chemicals Approval Organisation,
Weed Research Organisation, Kidlington, Oxford

Summary Results are presented from a series of 24 replicated small plot trials, in which chloroxuron at 3, 5 and 7 lb/ac was applied as a pre-emergence herbicide to 6 varieties of strawberry of varying ages between September 1961 and April 1963. Simazine was also applied in 5 of the trials. Chloroxuron at 5 lb/ac controlled Stellaria media, Senecio vulgaris, Capsella bursa-pastoris, Urtica urens and Chenopodium album. It failed to control Polygonum aviculare. Control of Poa annua, and Matricaria spp and Tripleurospermum maritimum ssp inodorum was variable.

Yields were not taken, but visual assessments indicate that although there may be a temporary check or chlorosis, especially after spring application, the crop recovers and grows normally. In the same series simazine caused damage when applied in the spring or to newly planted crops.

INTRODUCTION

Herbicides are now widely used in soft fruit, and provided crops are established in land free from perennial weeds it is possible to keep blackcurrants, gooseberries and raspberries weed-free with simazine, paraquat (and diquat), and spot treatments of dalapon and MCPB. In strawberries dinoseb, 2,4-DES, chlorpropham and chlorpropham plus fenuron have been used but they have never achieved great popularity. Simazine has proved to be a reliable herbicide under U.K. conditions and is now widely used in strawberries between July and December. Experience has shown that it is unsafe to treat spring planted crops until 6 months after planting - and autumn and winter planted crops until 9 months after planting. Spring application often causes damage, even to established fruiting beds.

Chloroxuron was first tested in the U.K. in 1961 on a number of crops including strawberries. Results were sufficiently promising to justify more extensive testing. The work reported here gives results from a series of 24 trials made by the National Agricultural Advisory Service between September 1961 and April 1963 on behalf of the Agricultural Chemicals Approval Organisation. Sites were distributed throughout the main strawberry growing areas of England and Wales, covering a wide range of soil types and including the commonly grown commercial varieties.

METHODS AND MATERIALS

The results presented are from replicated trials in which three doses of chloroxuron were compared with weed-free (hand weeded) and 'commercial' controls, the latter were kept weed-free by hoeing after the first flush of weeds had reached the young plant stage. Treatments were arranged in randomised blocks, there being 2 or 3 replicates in most trials.

Visual assessments of weed control and any effect on the crop were recorded on a linear scale of 0-10, where 0 = no weeds and 10 = maximum weediness, or in the case of the crop, maximum vigour. Plots were scored on two occasions for overall weediness, and individual species were classified as S, MS, MR and R, as defined in the Weed Control Handbook (3rd Edition). In addition to the score for crop vigour, abnormalities such as chlorosis were recorded separately.

Chloroxuron was applied at 3, 5 and 7 lb/ac in most trials, simazine was also used in certain trials at doses between 0.5 and 1.5 lb/ac, both herbicides were formulated as 50% w/w wettable powders.

RESULTS

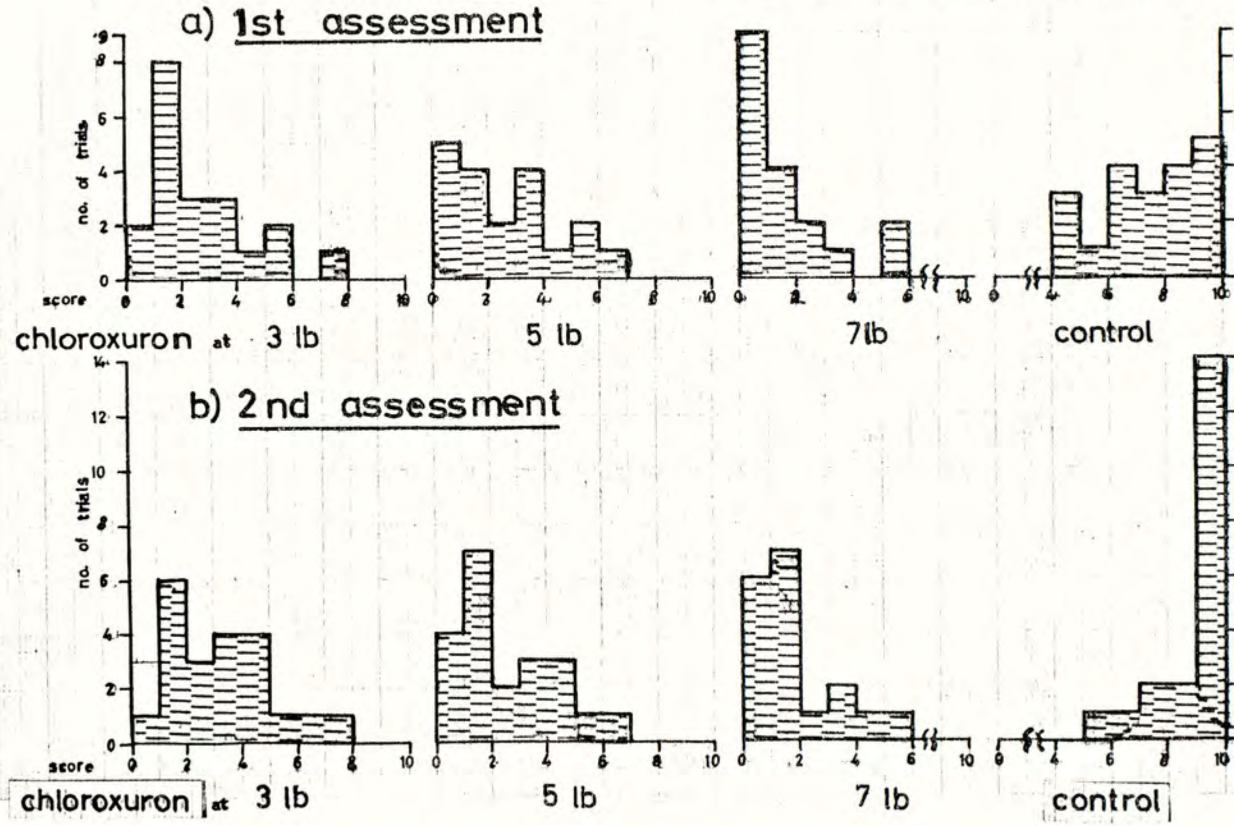
There were 24 trials in the series, but complete sets of assessments are not available for each trial therefore the total number of observations is usually less than the maximum possible (24). The main object of this series of trials was to evaluate the weedkilling properties of chloroxuron. Accordingly the results obtained are presented to show both the overall degree of weed control and the response of individual species. Notes were also made on crop abnormalities and these are presented, but it must be stressed that an effect on the foliage does not imply that the yield was affected. Yield data are not available.

Effects on weeds

Scores for general weediness when weeds on the control plots were in the seedling and young plant stage (1st and 2nd assessments respectively) are presented as histograms in Fig 1. Increasing the dose appreciably increased the number of trials in which the lowest weed score (0-10% survival) was recorded, with higher weed scores the effect of dose was not so pronounced. However, an allowance must be made for the total number of trials in each dose category. At the higher doses there were slightly fewer sites, thus, represented as a percentage these would appear more favourable. Of the 5 trials which included simazine a dose of 0.5 lb/ac gave better overall weed control than chloroxuron at 5 lb/ac in three (these were spring applications). In one trial results were comparable. In the remaining trial, where application was in the autumn, simazine was not as good as chloroxuron, but this result was anomalous in that chloroxuron gave good control of *Polygonum aviculare*.

The effect of chloroxuron on each weed species is of importance to the individual grower. Table 1 lists the number of trials in which each weed was recorded. In the present series the main weeds were *Stellaria media*, *Senecio vulgaris* and *Poa annua*, although the latter probably includes other annual grasses. Of secondary importance were *Polygonum aviculare*, *Matricaria spp* and *Tripleurospermum maritimum ssp inodorum*, *Capsella bursa-pastoris*, *Urtica urens* and *Chenopodium album*. Individual species showed a more pronounced response to dose than the full weed spectrum, this was more marked between 3 and 5 lb/ac than between 5 and 7 lb/ac. The two main broad-leaved weeds *Stellaria media* and *Senecio vulgaris* were both adequately controlled by 5 lb chloroxuron. Results with *Poa annua* have been extremely variable and even at 7 lb/ac this species was not controlled satisfactorily. The other weeds mentioned, with the exception of *Polygonum aviculare* and to a lesser extent *Matricaria spp* and *Tripleurospermum maritimum ssp inodorum* were well controlled.

Figure 1. SCORES FOR GENERAL WEEDINESS



The variation in 'mayweed' control may be due to species differences. Control of P. aviculare was unsatisfactory even at high doses, this being a major weakness since it occurred at approximately 40% of the sites. Among the other annual weeds that occurred at either one or two sites Anagallis arvensis, Polygonum convolvulus, Sinapis arvensis, Cerastium vulgatum, Galeopsis tetrahit, Papaver rhoeas, Solanum nigrum and Veronica agrestis were all classified as either S or MS to chloroxuron at 5 lb/ac. Fumaria officinalis, Polygonum persicaria, Sonchus oleraceus occurred in two trials and Galium aparine at one. With the exception of P. persicaria which was well controlled by 7 lb/ac, control of this group was unsatisfactory.

Table 1.

Susceptibility of individual weed species to chloroxuron

Species	dose chloroxuron (lb/ac)	susceptibility (no's refer to no. of trials) S	MS	MR	R	total
Stellaria media	3	11	5	2	0	18
	5	17	0	1	0	18
	7	15	1	0	0	16
Senecio vulgaris	3	7	4	4	1	16
	5	9	5	1	1	16
	7	12	2	0	1	15
Poa annua	3	3	2	7	3	15
	5	5	2	5	3	15
	7	6	4	3	1	14
Polygonum aviculare	3	0	0	7	2	9
	5	1	1	7	0	9
	7	0	2	6	0	8
Matricaria spp and Tripleurospermum maritimum ssp inodorum	3	0	1	5	1	7
	5	1	4	1	1	7
	7	2	2	1	1	6
Capsella bursa-pastoris	3	3	2	1	0	6
	5	6	0	0	0	6
	7	6	0	0	0	6
Urtica urens	3	3	1	1	0	5
	5	5	0	0	0	5
	7	5	0	0	0	5
Chenopodium album	3	1	2	0	1	4
	5	1	3	0	0	4
	7	3	0	0	0	3

Perennial weeds occurred as follows:- the number of trials for each is given in brackets, Cirsium arvense (6), Agropyron repens and Agrostis spp (3), Rumex spp (3), Ranunculus spp (2), Taraxacum officinale (2), Chrysanthemum leucanthemum (1), Rumex acetosa (1), Sagina procumbens (1) and Trifolium repens (1). Apart from one trial in which Cirsium arvense was classified as MS to chloroxuron at 3 lb/ac there was no control of these perennial weeds.

Where general weed control with 5 lb/ac chloroxuron was unsatisfactory it was found to be associated with a variety of factors, e.g. resistant weeds such as P. aviculare, dry weather following application or heavy soil. In one trial it was thought that bad application may be responsible although this was not supported by variation in scores between blocks.

Assessments of weed control were made when weeds on the control plots had reached a) seedling stage and b) young plant stage. This meant that the first assessment was made between 2 and 25 weeks after application. Second assessments were made between 4 and 40 weeks after application, 75% of the trials were assessed more than 6 weeks after spraying. At a number of sites established weeds were present at the time of application; these, with the exception of Stellaria media, which was controlled, were unaffected and are not included in the scores presented.

Effects on crop

In the 24 trials Cambridge Favourite occurred in 12, Cambridge Vigour in 7, Redgauntlet in 6, Talisman in 3, and Cambridge Rearguard and Merton Princess one each. In 12 trials chloroxuron had no noticeable effect on the crop. Plant vigour was reduced in two trials, but this was thought to be due to weed competition rather than a direct chemical effect. There was a transient reduction in plant vigour associated with chemical treatments in 6 trials but this was not noticeable at the second or final assessment. In three trials, in addition to a temporary effect on vigour chloroxuron caused chlorosis. This was either marginal, spreading to the centre of the leaflets, or in the form of mottling. Except in one trial where 7 lb/ac caused a permanent check the response was transient occurring from May until mid-late June. Varieties thus affected were Cambridge Favourite (2 trials), Redgauntlet (1) and Merton Princess (1). In the trial containing both Cambridge Favourite and Redgauntlet mottling was most pronounced on the latter. In each case application was in March or April 1963, to crops planted 6, 8 and 31 months earlier, but no common factor emerged. The crops which showed an initial check, were, with one exception, also sprayed in March, April or June, as were 7 of the crops which were unaffected throughout. Thus half of the 18 trials sprayed in the spring showed either slight check or transient chlorosis whereas only one of the 6 autumn-winter sprayed crops was checked. The outstanding trial showed marginal yellowing, but this was attributed to drift of a mercury spray applied to nearby apples.

Simazine was applied in five trials, in two, where 0.75 lb/ac was applied in October and December to Cambridge Favourite 3 weeks and 4 months after planting the crops appeared normal at harvest time, although those sprayed at 4 months after planting were checked initially. The remaining three trials (2 Cambridge Favourite and 1 Redgauntlet) were sprayed in March and April with doses of 0.5 to 1.5 lb/ac which resulted in severe damage.

DISCUSSION

Assessment of weed control is subjective, and assuming the chemical has no adverse effect on the crop the value of any chemical treatment to an individual grower is determined by comparison with the effectiveness of alternative herbicides, and mechanical weed control, taking into account such factors as efficiency, relative cost, and (in the case of handweeding) the availability of labour.

The less satisfactory results attributable to dry conditions and heavy soils and the inability of chloroxuron to control perennial weeds indicate that it is similar to most of the soil applied herbicides which have already been accepted by growers.

Chloroxuron, in controlling Stellaria media, Senecio vulgaris, Capsella bursa-pastoris, Urtica urens and Chenopodium album should be a useful herbicide in strawberries. Its inability to control Polygonum aviculare, and its unreliability against Poa annua and Matricaria spp and Tripleurospermum maritimum ssp inodorum is unfortunate since these occurred in a high proportion of trials, and it may be that there is little to commend the use of chloroxuron in situations where these are the major weeds. However, because of the difficulty in controlling Stellaria media mechanically under wet conditions this alone may make it a worthwhile treatment.

On the basis of five trials, simazine would seem to give better overall weed control than chloroxuron. Thus in situations where either herbicide may be used simazine is preferable. The present trials confirm that simazine causes damage to newly planted strawberries and when applied in the spring. Therefore for these two situations chloroxuron is the better choice.

The absence of yield data demands caution in interpretation of crop results. However, visual assessments suggest that, although chloroxuron may cause an initial check or transient chlorosis, (especially in spring), the crop recovers and becomes indistinguishable from non-sprayed plots. Thus it would seem that chloroxuron may be applied in the spring. Most trials were on crops which had been planted 6 months or more, but in the three which had only been planted for 3 weeks, 2 or 4 months there was no suggestion of increased toxicity to the crop. By contrast in two of these trials which included simazine the crop was damaged. Except in the trial where Merton Princess showed more severe chlorosis than Cambridge Favourite there was no indication of differential varietal susceptibility.

Although increasing the dose of chloroxuron from 3 to 7 lb/ac was found to improve the degree of weed control the data presented in Table 1 for the susceptibility of individual species points to 5 lb/ac as a suitable dose, above this there was little improvement.

Acknowledgements

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Chloroxuron was supplied by Messrs. Ciba Laboratories Ltd, Horsham, Sussex.

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INVESTIGATIONS USING CHLOROXURON AS A RESIDUAL HERBICIDE IN STRAWBERRIES

A.V. Lewis and M.R.L.W. Ayers

CIBA, HORSHAM, SUSSEX

Summary. Chloroxuron has been tested in the United Kingdom during the years 1961-64 as a residual herbicide for use on strawberries. The experiments show that it may be applied safely to fruiting strawberries in the spring and also to newly planted strawberries. Chloroxuron controls a wide range of annual weeds as they germinate and has a persistence varying from 6 to 10 weeks. There is no evidence of yield suppression following its use and no off-flavours or taints have been found in the fruit. Optimum application rates are 4 lb/ac active ingredient for light sandy soils and 5 lb/ac on heavier soils. For newly planted strawberries the best time of application is some 2 weeks after planting, and for fruiting beds during March and early April. Chloroxuron does not work on organic soils. There is no evidence to suggest that any particular commercial variety of strawberry is susceptible.

INTRODUCTION

Following synthesis and screening at CIBA, Switzerland, investigations were started in the U.K. during 1961 using chloroxuron as a residual herbicide on a variety of vegetable crops and strawberries. Economic considerations eventually narrowed the field of investigation to strawberries. An urgent need in this crop was for a safe residual herbicide for use in spring on fruiting strawberries and also on newly planted strawberries. Most residuals are only safe to use in autumn on fruiting beds and no residual herbicide is recommended for use on maidens, (Woodford E.K., and Evans, S.A., 1963). The trials were thus concentrated on the use of chloroxuron in spring and on maiden strawberries.

Earlier research in Switzerland (Geissbühler et al, 1963, a,b,c.) had shown how the herbicide behaved within the plant, its leaching characteristics and its rate of breakdown in the soil. Rates of application on various crops and soil types were also indicated.

METHODS AND MATERIALS

About 20 trial sites were laid down in the main strawberry growing areas of the U.K. The first trials were designed to discover the weed spectrum, persistence, symptoms of crop damage and the influence of soil type and climate upon its action. These trials were also designed to show the optimum application rate for varying soil types.

Doses of 4, 4.5 and 5 lb chloroxuron per acre were tested on plots measuring 3 x 2 yd and treatments were replicated 3 or 4 times. All treatments were applied to clean ground. Simazine at rates varying from $\frac{3}{4}$ lb/ac to $1\frac{1}{2}$ lb/ac, according to the soil type, was used as a comparative treatment in autumn.

Trials on fruiting beds were sprayed at different times from mid-March to mid-April, using an Oxford Precision sprayer at an equivalent rate of 100 gallons of water per acre and a spraying pressure of 40 lb per sq. in.

Weed scores and counts were taken regularly. If possible, total weed counts were made, otherwise 4 x 1 ft square quadrats were counted. Any visual effects upon the crop were also noted.

Following these initial trials, experiments were made to assess the effects of chloroxuron upon crop yield. In these trials the following treatments were used:-

Chloroxuron - 5 or 4 lb/ac
Chloroxuron - 10 lb/ac
Hoed control
Weedless control
Plot size - 5 yd x 3 yd
Replicates - 4

The weedless controls were hand weeded carefully as the weeds germinated with the minimum amount of soil disturbance.

Five trials were sited in Kent, Sussex, Vale of Evesham, Fens and Norfolk. The total yields from the plots were obtained over the harvest, no attempt being made to grade the fruit.

The trials were arranged to cover as many as possible of the different strawberry varieties. Samples of fruit were taken for taint testing and residue analysis.

RESULTS

Weed Spectrum.

The results of weed assessments from all the trials are summarised below, the species being divided into three categories; those fully controlled, those where up to 75% control was obtained and those where no worthwhile control was obtained.

A. Full Control.

Capsella bursa-pastoris
Chenopodium album
Senecio vulgaris
Sinapis arvensis
Stellaria media
Tripleurospermum maritimum spp inodorum

B. Up to 75% Control.

Anagallis arvensis — *Polygonum aviculare*
Lamium purpureum — *Polygonum persicaria*
Poa annua — *Veronica spp.*

C. No Control.

Fumaria officinalis
Polygonum convolvulus

Chloroxuron has no effect on perennial weeds such as Rumex spp. or Cirsium arvense or Convolvulus arvensis.

Yield Results.

The yield figures from a selection of trials sprayed in the spring are shown in Table 1.

Table 1.

Strawberry Yield Trial Results

AREA - Fens
SOIL - Medium silty loam
VARIETY - Huxley - planted October 1960
SPRAYED - 20.4.63 onto clean soil
HARVESTED - July 1963

Treatment	Yield in TONS per ACRE
5 lb/ac chloroxuron	3.91
10 lb/ac chloroxuron	3.65
Hoed control	3.58
Weed free control	4.33

There is no significant difference between the treatments at $P = 0.05$.

AREA - Vale of Evesham
SOIL - Medium loam
VARIETY - Cambridge Vigour - planted November 1960
SPRAYED - 27.4.63 onto clean soil
HARVESTED - 21.6.63 to 10.7.63

Treatment	Yield in TONS per ACRE
4 lb/ac chloroxuron	4.16
8 lb/ac chloroxuron	4.58
Hoed control	4.67
Weed free control	4.68

The yield from the 4 lb chloroxuron treated plots is significantly lower than the others although the weed control was adequate and so weed competition is not the factor causing yield reduction. This is the standard rate for this soil and it is interesting to note that double the normal dose has caused no yield reduction.

Table 2 shows the yield from 3 varieties of strawberry which have had only chemical weed control since planting.

Table 2.

PLANTING DATE - 14.12.62 SOIL - heavy clay
SPRAYING DATES - 6. 5.63
23. 9.63
29. 3.64

Treatment	Variety and YIELD in TONS per acre		
	CAMBRIDGE FAVOURITE	TALISMAN	RED GAUNTLET
5 lb chloroxuron	7.9	5.1	5.4
10 lb chloroxuron	7.05	4.8	5.5
Hoed control	7.5	4.9	4.9
Weed free control	7.5	5.4	5.05

There is no significant difference at the $P = 0.05$ level in the yields of the treatments in each variety.

The results from the other yield trials were similar to those quoted.

Varietal Differences.

Experiments were conducted on the following varieties:-

- Cambridge Favourite
- Huxley
- Talisman
- Redgauntlet
- Cambridge Vigour
- Merton Princess
- Royal Sovereign

None of these varieties were damaged even with a dose of 10 lb/ac. There is thus no evidence of varietal differences in susceptibility.

Taint.

Samples of strawberries which had been sprayed with chloroxuron were tested for taint at the Fruit and Vegetable Canning and Quick Freezing Research Association. The following table 3 shows the spraying, harvesting and canning dates of the trials.

Table 3.

VARIETY	SPRAYING DATE	HARVEST DATE	CANNING DATE
Cambridge Favourite	10.3.62	10.7.62	10.7.62
Cambridge Vigour	3.4.62	11.7.62	11.7.62
Cambridge Favourite	7.4.62	20.7.62	20.7.62

No taints or off flavours were detected.

Residues.

Samples of strawberries from four sites have been analysed for chloroxuron residues. The following table 4 shows the results of this work.

Table 4.

SITE	VARIETY	SPRAY DATE	TREATMENT	APPARENT CHLOROXURON in mg/100g (not corrected for blank) HARVEST DATES		
				3.7.62	20.7.62	27.7.62
E.Anglia	Cambridge Favourite	23.3.62	Untreated	7.5	7.0	7.2
			2½lb chloroxuron	9.3	8.5	4.0
			5 lb chloroxuron	10.0	7.3	7.3
				6.7.62	10.7.62	25.7.62
Sussex	Cambridge Favourite	10.3.62	Untreated	9.0	no sample	
			5 lb chloroxuron	5.0	5.8	5.0
				11.7.62	18.7.62	26.7.62
West Midlands	Cambridge Vigour	3.4.62	Untreated	7.0	no sample	
			5 lb chloroxuron	3.0	10.0	5.5
				4.7.62		
W.R.O. Oxford	Cambridge Favourite	17.4.62	Untreated	4.0		
			5 lb chloroxuron	6.0		

Residues of chloroxuron are negligible in strawberries which have been sprayed before the flowers open. Usually the interval between spraying and harvest was about four months.

Maiden Strawberry Trials.

Chloroxuron was used in 6 trials annually on newly planted strawberries. The optimum application time appears to be about 2 weeks after planting. If there is a great deal of weed growth, then chloroxuron must be applied earlier. The two week period appears to allow the strawberry to become established and reduces visible damage symptons. Although a small percentage of the maidens may show chlorotic yellowing of the leaves, all new growth is damage free and the strawberries grow away unchecked.

Application Rates.

The trials show that the application rates should be 4 lb/ac on light sandy soils and 5 lb/ac on heavier soils. Examples are given below of weed observations on different soil types.

SOIL TYPE	APPLICATION RATE	SPRAY DATE	INSPECTION DATES and WEED SCORE 0 - 100% control. 10 - no control		
			1.5.63	28.5.63	10.6.63
Light sandy soil	4 lb/ac	9.4.63	0	0	1
	5 lb/ac		0 *	0	0
Silt fen	4 lb/ac	7.4.63	0	1	2
	5 lb/ac		0	0	0
Heavy clay	4 lb/ac	10.4.63	1	2	6
	5 lb/ac		0	0	1

* - occasional crop damage, manifesting itself as severe yellowing and chlorosis of the leaves.

Dominant Weed Species At Above Sites

Light sandy soil	Stellaria media	Chenopodium album
	Senecio vulgaris	Poa annua
	Capsella bursa-pastoris	
Silt fen	Senecio vulgaris	Chenopodium album
	Stellaria media	Urtica urens
	Capsella bursa-pastoris	Veronica spp.
Heavy clay	Senecio vulgaris	Urtica urens
	Stellaria media	Sinapis arvensis
	Poa annua	Potentilla reptans
	Tripleurospermum maritimum spp inodorum	

DISCUSSION

The work done in the years 1961 - 64 shows that chloroxuron is a safe residual herbicide for use in fruiting strawberries and on newly planted strawberries.

It would appear that the grower is now able to control weeds in strawberries by chemical methods from the date of planting. By obviating hand hoeing, the growers costs should be reduced considerably.

There is no evidence to show that chloroxuron builds up in the soil and, in fact, earlier work (Geissbühler et al, 1963, c) has shown that after some 8 weeks at least 35% of the chloroxuron has been broken down by biological means. It would appear that there is little or no risk in the level of chloroxuron building up to such an extent that crops following the strawberry crop would be damaged.

A weed control persistence of at least 6 weeks may be expected from chloroxuron. A complete weed control programme would necessitate at least 3 chloroxuron sprays per annum. At present, work is being undertaken to ascertain the effect upon the strawberry crop of a herbicide programme consisting of an autumn simazine treatment and a spring chloroxuron treatment.

Chloroxuron was first marketed in the autumn of 1963, and experience from then and the spring of 1964 shows chloroxuron to be living up to its promise. There have been isolated cases of crop damage, but these have invariably been associated with wrong use of the chemical.

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FURTHER PROGRESS REPORT ON STRAWBERRY HERBICIDE EXPERIMENTS AT MYLNEFIELD

R. J. Stephens

Scottish Horticultural Research Institute,
Invergowrie, Dundee, Scotland.

Summary It is shown that simazine at 2.0 lb/ac or neburon at 10.0 lb/ac, applied in either case in two equal parts in spring and autumn, can significantly reduce the growth and cropping of Talisman strawberries in comparison with a cultivated control treatment.

In a second strawberry trial three applications of chloroxuron, each preceded by shallow hoeing, gave good control of annual weeds for more than twelve months after planting. A slight reduction of yield was caused in Talisman but none in Cambridge Vigour, Redgauntlet or Merton Princess.

INTRODUCTION

Previous work on strawberries in Scotland reported by Sutherland (1960) and Stephens (1962) showed that low rates of simazine effectively controlled annual weeds, although in one case at the expense of some reduction in yield. Further experience is now reported in which this loss of yield occurred, together with preliminary results of a newer trial designed to compare the performance of strawberries under (i) the traditional method of hand-hoeing within the rows accompanied by light rotary cultivation in the alleyways and (ii) chemical control of weeds combined with a minimum of cultivation. The latter regime began with the use of chloroxuron for the first year after spring planting and will be continued with the annual use of simazine in autumn.

MATERIALS AND METHODS

The older of the two experiments reported here has already been described (Stephens, 1962). The simazine, dacthal and neburon treatments, each applied in two equal spring and autumn applications, have been continued, and the mean heights and widths of the plants under treatment have been measured with a simple gantry device spanning the row.

In 1963, a second replicated trial was planted in mid-May with the varieties Talisman, Cambridge Vigour, Redgauntlet and Merton Princess. Each unit plot in this consists of two rows side by side and 39 ft. long, and the plots are separated by single guard rows. The cultivated plots have been kept clean by hand and by shallow inter-row rotary cultivation as required. It was intended to apply chloroxuron about ten days after planting, but the first application of 6.0 lb/ac was delayed because of inclement weather. When spraying became possible, some five weeks after planting, the weeds which had developed were cleared beforehand by dutch hoeing. Further sprays were applied at 4.0 lb/ac in September 1963 and 5.0 lb/ac in April 1964, each being preceded by a light hoeing to destroy surviving annual weeds.

Fruit from the treated plots was submitted to the British Food Manufacturing Industries Research Association's laboratories at Leatherhead for taint tests on jam made from the fresh samples.

RESULTS

The yield data from the first of these trials clearly show that both simazine and neburon can be damaging to Talisman strawberries when applied at 2.0 lb/ac and 10.0 lb/ac respectively in two equal parts in spring and autumn. Yields were reduced and in spring 1964 plant size too was significantly reduced. (The differences in mean width which are not given, showed the same trend as the figures for height.)

The control of annual weeds by simazine was good in this trial virtually no hand labour having been required for weeding. Dacthal, however, provided only a very slight check on the growth of broad-leaved annual weeds. Neburon was intermediate in its effect, working well only when application was followed by rain.

In the second trial, the three applications of chloroxuron did not cause a significant reduction in the yield of strawberries in three of the varieties in 1964 (Table 2), but in the variety Talisman there was a slight reduction. There were some signs of chlorisis after the first application but the plants were not apparently reduced in vigour.

Chloroxuron applied to clean soil shortly after a very light surface cultivation controlled most species of annual weeds for two to three months, and three applications in addition to three light hand-cultivations were sufficient to keep the plots clean. The principal surviving weed was annual meadow grass (Poa annua), which was accompanied by a few plants of groundsel (Senecio vulgaris). It proved impossible to keep the control plots entirely weed free by cultivation.

No taint has been detected in jam made from fresh fruit from the plots treated with simazine, dacthal or neburon. Results are not yet available for the treatments in the more recent trial in which chloroxuron was applied.

TABLE 1

Fruit yield in cwt. per acre and mean heights in cm.

size of plot harvested: 11.3 sq. yd.

	Yield in cwt/ac					Mean height in cm
Treatment	1961	1962	1963	1964	TOTAL	1964
control-cultivated	66.1	137.9	142.5	124.3	470.8	28.8
simazine 2.0 lb/ac	50.9	125.0	123.1	116.3	415.3	26.7
neburon 10.0 lb/ac	57.0	119.5	115.7	95.0	387.9	25.1
dacthal 12.0 lb/ac	68.8	139.1	131.9	120.0	459.8	27.2
standard error per plot	9.5	12.9	17.1	8.5	21.6	1.4
significance of F test	5.0%	5.0%	N.S.	1.0%	0.5%	5.0%

TABLE 2

Fruit yields in cwt/ac

size of plot harvested: 24 sq. yd.

Treatment	Talisman	C. Vigour	Redgauntlet	Merton Princess
control-cultivated	53.91	88.51	48.85	54.76
chloroxuron 6 + 4 + 5 lb/ac	48.90	93.64	48.29	53.89
standard error per plot	1.4	8.8	3.87	15.01
significance of F test	2.5%	N.S.	N.S.	N.S.

DISCUSSION

The existing tentative recommendation for using simazine in fruiting strawberries is to apply it in the autumn, after picking, and not in the spring. Trials elsewhere in Britain have shown that simazine used in spring can damage the plants, especially if an application has also been made in the previous autumn. (Ivens, 1962).

Simazine has not been recommended for application to newly planted runners, and it is usually recognized that the plants should be well established before a treatment is commenced. It has been shown that activated charcoal applied to the roots of runners before planting can under some circumstances render the early application of simazine to newly planted runners less hazardous (Ministry of Agriculture, N. Ireland, 1963), but this method is not yet proven in all areas. Need remains for a safe and effective strawberry herbicide which can be applied soon after planting, before weeds have established themselves, and chloroxuron is probably the most effective of the commercially available materials suitable for use at this stage. In the trial reported, three applications in addition to some hand cultivation were sufficient to keep the plants clean for more than a year from planting. Each chloroxuron application is both more expensive and less long lasting than an application of simazine, but such greater expense may be justified in the interests of crop safety.

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A COMPARISON OF CHEMICAL AND CULTURAL METHODS OF WEED CONTROL IN RASPBERRIES

D.W. Robinson*
Horticultural Centre, Loughgall, Co. Armagh.

Summary. Results are presented of a soil management trial in raspberries carried out over a five year period. Four systems of management of the alleys and three systems in the cane row were compared using a split-plot design. The results showed that raspberries may be grown without any soil cultivation where herbicides are used to control weeds. This system did not result in increased yields but weed control was more effective and, in the long-term, less expensive than conventional cultivation.

The soil cap that formed on non-cultivated plots had no adverse effect on plant performance. Annual applications of farmyard manure at 15 ton/ac and grassing-down prevented soil capping but crop yield was slightly reduced on grassed plots in 1964.

INTRODUCTION

The results of trials investigating the effect of eliminating cultivation in blackcurrants (Robinson 1963a) and strawberries (Robinson 1963b) have been presented. These trials showed that a system of weed control based entirely on herbicides with no soil disturbance was a promising alternative to cultivation in both crops. The results of a similar trial in raspberries are presented in this paper.

MATERIALS AND METHODS

The raspberries, variety Malling Jewel, were planted 2 ft apart in rows spaced 7 ft apart in November 1959. The land sloped to the east with a gradient of 1 in 12 at the steepest part. The soil, a bright brown clay loam, developed from local carboniferous limestone drift contained in the 0 - 4 in. layer approximately 25% coarse sand, 40% fine sand, 10% silt and 20% clay. Farmyard manure at 20 ton/ac was ploughed down before planting. After planting the canes were cut down to 6 in. in accordance with normal practice.

The experiment was laid out as a split-plot design with four treatments of the alleys (cultivation, grassing down, herbicide treatment alone and herbicide treatment + manure mulch) as main plots and three treatments of the cane row (hand cultivation, herbicide treatment alone and herbicide treatment + manure mulch) as sub-plots. Each main plot was 33 yd long by 7 yd wide (three alleys 33 yd long by 7 ft wide), the alley treatments being applied to the centre 4 ft of each alley. Sub-plots were 11 yd long and consisted of two parallel lengths of cane row. The treated area extended 18 in. on each side of each cane row. The outside rows of main plots served as guard rows. Alley treatments (main plots) were replicated three times and cane row treatments (sub-plots) twelve times. The trial, including cross alleys between blocks, occupied an area of approximately ¾ ac. Each winter

* Present address - Agricultural Institute, Kinsealy, Malahide, Co. Dublin.

farmyard manure was applied at a rate of 15 ton/ac to the herbicide-treated, mulched cane rows and to all alleys except those in the herbicide-treated, unmulched plots. In the grassed-down alleys the grass grew up through the manure mulch in the spring, in the cultivated alleys the manure was incorporated to a depth of about 3 in. and in the herbicide-treated, mulched alleys and cane rows it was allowed to remain as a layer on the surface.

In accordance with normal practice an NPK fertilizer was applied evenly to all plots each February and May, the mixture being varied according to soil analysis and the appearance of the crop. Alleys not treated with manure were given extra fertilizer each February equivalent to 45 units of N, 20 units of P and 70 units of K per acre.

The main weeds in the experimental area were Poa annua (annual meadow grass), Stellaria media (chickweed) and Senecio vulgaris (groundsel). The ground was substantially free from perennial weeds at planting time but Ranunculus repens (creeping buttercup), Taraxacum officinale (dandelion) and Agrostis stolonifera (creeping bent) occurred occasionally. Weed counts were made each spring on 20% of the area of each plot.

The different weed control and soil management treatments began in March 1960. In cultivated alleys and cane rows weeds were suppressed as necessary by rotary hoeing and hand hoeing respectively. The alleys were cultivated to a depth of 3 to 4 in. and the cane rows to a depth of ½ to 1½ in. In each of the five years 1960 to 1964 both operations were usually carried out four times between February and June.

The spray programme used to control weeds on herbicide-treated plots was not planned in detail beforehand but the most suitable treatment was used according to which species were present or expected. The selectivity of the herbicides used was determined beforehand in replicated experiments in nearby plantations (Anon. 1961, 1962, 1963). Details of the spray programme applied on mulched and unmulched herbicide-treated rows and alleys are shown in Table 1. The sprays were applied by means of a pressure-retaining knapsack sprayer in a volume of 40 gal/ac and at a pressure of 25 lb p.s.i. Where spot-treatments were necessary these were applied in calm weather only.

In the grassed alleys the sward was allowed to tumble down in spring and early summer 1960. The sward consisted mainly of Poa annua and Agrostis stolonifera with occasional plants of Holcus lanatus and Lolium perenne. Broad-leaved weeds in the grass were eliminated by cutting and by an application of MCPA in September 1960. The sward was cut four or five times each season between March and June.

Table 1

Herbicide programme used to control weeds and suckers in herbicide-treated alleys and cane rows (March 1960 - October 1964)

Time of Application	Main 'weeds' present	Herbicide lb/ac	Method of application
1960			
March	None	Simazine 2 (1)	Overall
June	Ranunculus repens	Diquat 1 (2)	Spot treatment
July	Germinating seedlings	Simazine 1½	Overall
September	Ranunculus repens, Taraxacum officinale	MCPA 2 (3)	Spot treatment
November	Ranunculus repens, Poa annua Stellaria media	Paraquat 1 (4)	Spot treatment
1961			
March	None	Simazine 2	Overall
April	Raspberry spawn	Diquat 2	Spot treatment
May	Raspberry spawn	Diquat 2	Spot treatment
June	Raspberry spawn	Paraquat 2	Spot treatment
August	Germinating seedlings	Simazine 1	Overall
November	Poa annua, Senecio vulgaris, Agrostis stolonifera	Paraquat ½	Spot treatment
1962			
March	None	Simazine 2	Overall
April	Raspberry spawn	Paraquat 2	Spot treatment
May	Raspberry spawn	Paraquat 2	Spot treatment
June	Raspberry spawn	Paraquat 2	Spot treatment
November	Ranunculus repens, Agrostis stolonifera	Paraquat ½	Spot treatment
1963			
March	None	Simazine 1½	Overall
November	Poa annua, Senecio vulgaris	Paraquat ½	Spot treatment
1964			
March	None	Simazine 1½	Overall

(1) Gesatop
(2) Reglone
(3) Agroxone K
(4) Gramoxone

Sucker growth was prolific throughout the experimental area in spring 1961, 1962 and 1963. The suckers in the cane row were allowed to form continuous 'hedges' of non-stooled canes and the plants were not maintained as separate stools. Unwanted suckers in cultivated and grassed alleys were suppressed by cultivation and mowing respectively. In 1961 and 1962 suckers in herbicide-treated alleys were controlled by applications of diquat or paraquat. Although effective, two or three applications were needed each year. In 1963 and 1964 satisfactory control was obtained at less cost by mowing the suckers about 1 in. above soil level during the second week in June when the suckers were about 2 ft high. Suckers arising in the cane row were confined to a narrow band about 9 in. wide; this was achieved by hoeing where the cane row was cultivated and by careful spot-treatment with diquat or paraquat (1961 and 62) and by mowing (1963 and 64) where the cane row was not cultivated. Cane growth was generally satisfactory on all plots. Each winter, canes were spaced 3 in. apart on the wire supports and cane height was reduced to 5 ft in March.

RESULTS

Effect on growth and yield

In 1961 and 1962 very slight chlorosis occurred on young spawn in the cane row following treatment with paraquat. This injury was apparently due to translocation of the herbicide from treated suckers in the alley. The injury was temporary and had no effect on the subsequent development of the spawn. The other herbicides used caused no obvious injury throughout the five year period.

Yield data (Table 2) showed that there was no significant difference in crop yield between treatments in any year although the yield from grassed-down plots was slightly reduced in 1964 irrespective of the treatment in the cane row. Measurements of cane number and cane height made each autumn before pruning in 1960, 61, 62 and 63 also revealed no significant difference between treatments.

Effect on weed control

Weed counts made each spring showed marked differences in control between treatments. In all years weeds were controlled more effectively on herbicide-treated plots than in cultivated plots. On sprayed plots weeds seldom covered more than 5% of the area throughout the experimental period. The most effective control of weeds in the cane row was obtained where herbicides were used both in the cane row and in the alleys irrespective of mulching treatment. Weeds were controlled least effectively where both alleys and cane rows were cultivated. Weed control was intermediate where the alleys were cultivated and the cane rows sprayed, where the alleys were sprayed and the cane row cultivated, and where the alleys were grassed down and the cane row cultivated. The results of a weed count made in the cane row is shown in Table 3. This count was made on 8 May 1964, three weeks after hand hoeing and two months after spraying. The data show that hand hoeing in the cane row gave significantly less control of weeds than either of the herbicide treatments ($P = 0.01$). An interaction of alley and cane row treatments was also present ($P = 0.05$). Each autumn, differences in weed control between treatments were even more pronounced.

Table 2

Effect of method of management of alley and cane row on crop yield

Treatment of alley	Year	Crop yield; cwt/ac			Alley mean
		Treatment of cane row			
		Herbicides only	Hand hoeing	Herbicides plus manure mulch	
Herbicides only	1961	54.5	52.9	52.7	
	1962	85.4	88.0	88.3	
	1963	99.0	100.0	101.0	
	1964	86.3	89.1	87.1	
	Total	325.2	330.0	329.1	328.1
Herbicides plus manure mulch	1961	53.2	53.3	48.9	
	1962	76.7	82.4	80.2	
	1963	100.5	102.5	102.4	
	1964	83.2	80.4	82.2	
	Total	313.6	318.6	313.7	315.3
Grassing-down plus manure mulch	1961	51.8	50.6	49.8	
	1962	83.3	80.4	85.8	
	1963	110.4	101.7	104.3	
	1964	71.8	66.1	70;0	
	Total	317.3	298.8	309.9	308.6
Cultivation plus manure	1961	49.6	53.1	53.7	
	1962	78.3	85.8	82.0	
	1963	105.6	102.6	103.4	
	1964	86.8	81.9	82.8	
	Total	320.3	323.4	321.9	321.8
	Cane row mean	319.1	317.7	318.6	

Effect on soil conditions

A surface cap formed on herbicide-treated, unmulched plots during the winter following planting and persisted throughout the period of the experiment. This cap was broken by soil cracking during dry weather and by the activity of earthworms. Annual applications of manure prevented the formation of a surface cap on herbicide-treated mulched plots but slight surface cracking occurred during dry weather. No obvious soil capping or cracking appeared on cultivated or grassed-down plots. Although

Table 3

Effect of method of management of alley and cane row on weed control in the cane row

Treatment of alley	Total no. of weeds per ft^2 - May 1964 Transformed data ($\sqrt{x}$)			Alley mean
	Treatment of cane row			
	Herbicides only	Hand-hoeing	Herbicides + manure mulch	
Herbicides only	0 (0)	2.8 (1.57)	0.04 (0.10)	0.96 (0.56)
Herbicides plus manure mulch	0 (0)	3.3 (1.61)	0 (0)	1.1 (0.54)
Grassing down plus manure mulch	0.04 (0.10)	8.8 (2.87)	0 (0)	2.9 (0.99)
Cultivation plus manure	0.40 (0.43)	11.7 (3.33)	0.17 (0.30)	4.1 (1.36)
Cane row mean	0.11 (0.13)	6.7 (2.35)	0.05 (0.10)	

Analysis - transformed data

S.E. of alley mean $= \pm 0.196$

S.E. of cane row mean $= \pm 0.131$

S.E. of interaction mean (alley x cane row) $= \pm 0.289$

severe run-off and erosion occurred on non-cultivated plots in other experiments at Loughgall (Robinson 1963b, 1964b) there was no obvious evidence of erosion from any plot in this trial where the ground sloped less steeply.

DISCUSSION

Probably the most notable result of this trial is the absence of marked differences in yield between treatments. In spite of the fundamental differences in method of soil management, and although some plots received farmyard manure and others fertilizers only, no obvious yield differences between treatments occurred until 1964. This result suggests that, provided soil and climatic conditions are favourable, the raspberry is able to adapt itself to a range of contrasting methods of soil management.

It seems possible that the slight reduction in yield on grassed-down plots in 1964 was due to increasing competition by the sward for moisture and nutrients. Lower yields of raspberries where a cover crop was grown in the alleys have also been recorded in Scotland (Wood et al 1960) and in New Zealand (Porter 1963). A further disadvantage of grassed alleys in this trial was the tendency for weeds to invade the cane row from the sward; in this respect Agrostis stolonifera, Ranunculus repens and Trifolium sp. were particularly troublesome.

Higher crop yields of blackcurrants (Robinson 1963a) and gooseberries (Robinson 1964a) have been recorded where cultivation has been replaced by a system of soil management based on the use of herbicides. Although the plantations were situated in the same field and the trials carried out under similar conditions there was no indication of any increase in yield of raspberries on non-cultivated plots in the present trial.

Excavations carried out in September 1963 on blackcurrants (variety Baldwin) and raspberries (variety Malling Jewel) growing in adjacent plantations under systems of cultivation and non-cultivation also gave contrasting results. On cultivated plots the surface roots of both fruits had been destroyed down to the depth of cultivation. Where cultivation had been eliminated the roots of blackcurrants had developed prolifically in the top 3 in. of soil. Under similar conditions there was no extensive development of raspberry roots close to the surface. Although most of the root system of the raspberries occurred in the top 12 in. there was no evidence of preferential rooting in the surface 3 in. where cultivation was eliminated.

If these findings apply to blackcurrants and raspberries grown elsewhere, shallow cultivation would be less likely to damage the root system of the raspberry than of the blackcurrant. This may account for the absence of any beneficial response in raspberries in this trial following the elimination of shallow cultivation.

The data in Table 3 show that better control of weeds was obtained in the cane row where the adjacent alley was sprayed with herbicides than where it was cultivated. This was apparently due partly to weeds germinating in soil thrown onto the sprayed surface by the rotary hoe and to the tendency for weeds to invade the cane row from the cultivated alleys in the autumn.

There was a gradual decrease in the weed problem on herbicide-treated plots during the five year period. Possible causes for the reduction in the number of weed seeds germinating in non-cultivated plots have been discussed (Robinson 1964b). As a result of the decrease in the weed problem, an application of simazine at 1½ lb/ac in March 1963 and again in March 1964 was sufficient to keep the ground virtually weed free for the remainder of the year. Spot-treatment with paraquat in November was almost unnecessary and the total cost of herbicides for weed control in the fourth and fifth year was less than £6 per acre per annum. The annual cost of controlling suckers by mowing was also small being less than £2 per acre. No information on the annual cost of controlling weeds and suckers by cultivation was obtained in this trial but it was undoubtedly higher than £8 per acre. Thus, on soils where non-cultivation is practicable, striking benefits can be obtained by growers who are able to prevent weeds from seeding for two or three years. No apparent reduction of the weed problem occurred on cultivated plots during the period of the experiment. While weeds were well controlled by cultivation in the alleys and cane rows during the spring, it was not practicable because of cane growth to rotary hoe or hand hoe from late June until after pruning and tying-in during the winter. In some years wet soil conditions further prevented cultivation until March. Consequently on cultivated plots weeds were able to grow and seed undisturbed for long periods.

The results of this trial suggest that under similar conditions a system of soil management based on the use of herbicides is superior to conventional cultural practice. The advantage of eliminating cultivation does not lie in increased yields but in ease of management and in long-term saving in cost of weed control.

The risk involved in abandoning cultivation where perennial weeds are prevalent has been discussed (Robinson 1964b). Complete control of weeds with herbicides was easily established in this trial because the site was reasonably free from perennial species before planting. In these circumstances simazine and paraquat gave good control of most of the weeds present.

Varieties of raspberry would be expected to vary considerably in suitability for a system of management based on the use of herbicides for weed control and mowing to suppress surplus suckers. The variety used in this trial, Malling Jewel, is particularly suitable because of its upright growth and habit of producing a moderate number of suckers only.

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

R. J. Stephens

Scottish Horticultural Research Institute, Invergowrie, Dundee.

Summary Trials with soil-acting herbicides applied to raspberry plantations each spring for up to 6 years have shown that it is possible to achieve good control of annual weeds without either detectable harm to the plants, reduction in yield, or tainting of the crop.

Perennial weeds continue to be a problem among raspberries in plantations ill-sited or suffering from neglect, and preliminary results with overall treatments of bromacil, 2,6-dichlorothiobenzamide and granular atrazine suggest that these herbicides could probably be used for spot-treating patches of perennial weed without permanently damaging the crop.

INTRODUCTION

The use of substituted urea and triazine herbicides in raspberries has now been investigated for several years at this Institute and at other centres in the United Kingdom. Results reported previously from Scotland have shown simazine to be a safe and effective herbicide for use both in raspberry fruiting plantations (Wood et.al., 1960; Stephens, 1962) and in cane nurseries (Stephens and Sutherland, 1962).

Two long-term trials reported at the 6th British Weed Control Conference have been continued, and a further experiment was established in spring 1963 to evaluate the effects of certain herbicides combined variously with degrees of cultivation, rate of N manuring and the presence or absence of a light mulch of well-rotted manure. A fourth trial was planted here in spring 1964 to evaluate the use in raspberries of atrazine granules (2.0 lb/ac), 2,6-dichlorothiobenzamide granules (4.0 lb/ac), bromacil (2.0 lb/ac) and simazine (2.0 lb/ac). Wettable powder formulations of bromacil and simazine were used. Both new trials are on medium loam soil carrying some scattered patches of perennial weeds (mainly coltsfoot, *Tussilago farfara*) in addition to the annual weeds mentioned in previous reports.

METHODS AND MATERIALS

The long-term experiments planted in 1959 and 1960 have already been described (Stephens, 1962). Management of these trials has continued along the lines stated, with all the internal alleyways receiving shallow rotary cultivation wherever this has been required by the untreated control plots. Surplus suckers and surviving weeds in the rows have been removed with dutch hoes.

The first of the two new experiments, planted in spring 1963 with Malling Jewel contains eight treatments replicated six times, with each plot sub-divided for high and low nitrogen. Table 3 gives a complete list of the treatments. The levels of fertilizer applied in pounds per acre nitrogen were:-

	Low N	High N
Year of planting (1963)	15	40
Second year (1964)	15	55

Phosphate and potash were applied at 33 lb/ac P_2O_5 and at 80 lb/ac K_2O in both 1963 and 1964. The mulched treatments had well-rotted farmyard manure applied at 10 tons per acre one year after planting.

The overall liquid sprays were applied by O.P.S. in the spring, each at a volume rate of 40 gal/ac and the granules in the 1964 experiment were applied in spring by hand. Paraquat was applied by knapsack sprayer with a single nozzle or by a small hand-held dribble-bar.

Fruit samples from plots under all the herbicide treatments used in these trials have from time to time been sent to the British Food Manufacturing Research Association laboratories at Leatherhead, where jam made from them has been assessed for taint.

RESULTS

None of the chemical treatments have as yet significantly reduced the fruit yield of either Lloyd George or Malling Jewel, but results are not yet available from the latest trial with atrazine, bromacil and 2,6-dichlorothiobenzamide. The data for cane growth in the older experiments was not significant at P = 0.05, and is not shown in this report.

Simazine, monuron and diuron used annually and an annual alternation of simazine and monuron have all given satisfactory control of annual weeds in these trials. In the older trials the cleanest treatments have been simazine and simazine/monuron, but a few weak plants of speedwell (Veronica spp.) and groundsel (Senecio vulgaris) have survived on the monuron and diuron plots. In the trial planted in 1963 small numbers of cleavers (Galium aparine), annual nettle (Urtica urens) and fumitory (Fumaria officinalis) have survived the simazine treatment. In the most recent (1964) trial, granular atrazine was ineffective for several months, but after a shallow dutch hoeing was given few annual weeds appeared. Bromacil and 2,6-dichlorothiobenzamide have both given excellent annual weed control, and the latter has partially controlled coltsfoot.

In tests made by testing panels at Leatherhead, no off-taints have been found associated with simazine, diuron or monuron. Results are not yet available for the plots treated with bromacil, atrazine or 2,6-dichlorothiobenzamide.

Table 1.

Long term raspberry experiment planted in 1959

Raspberry yield in cwts. per acre

		1961	1962	1963	1964	1961-64
Control		85.7	59.9	54.9	106.1	306.6
Simazine	2.5 lb/ac	85.4	67.8	63.4	117.3	333.9
Monuron	3.5 lb/ac	71.2	67.2	58.9	106.9	304.2
2,4-DES + Fenuron	4.6 lb/ac 0.5 lb/ac	84.3	69.3	63.8	105.2	322.6
2,4-DES + Propham	4.6 lb/ac 4.0 lb/ac	86.9	54.4	58.4	114.7	314.4
Standard error per plot		9.8	2.1	4.3	8.3	23.5
Significance of F test		N.S.	1.0%	5.0%	N.S.	N.S.

Table 2

Long term raspberry experiment planted in 1960

Raspberry yield in cwts. per acre

		1961	1962	1963	1964	1961-64
Control		30.3	56.9	64.0	71.1	222.3
Simazine	1.5 lb/ac	30.3	68.4	73.5	78.1	250.3
Monuron	3.0 lb/ac	25.1	66.3	71.7	67.9	231.0
Diuron	3.0 lb/ac	26.1	64.0	72.8	66.6	229.5
Simazine or Monuron	1.5 lb/ac 3.0 lb/ac	29.4	68.3	72.5	75.7	245.9
Standard error per plot		3.9	10.1	14.1	6.2	28.2
Significance of F test		N.S.	N.S.	N.S.	N.S.	N.S.

Table 3.

Long term raspberry experiment planted in 1963

Fruit yields for 1964 and production of new canes 1963/64

Treatment	Fruit yields in cwt/ac		Number of new canes per plot	
	Low Nitrogen	High Nitrogen	Low Nitrogen	High Nitrogen
Normal cultivation [1] + digging in the autumn	23.53	23.53	37.7	44.2
Normal cultivation	26.78	26.39	41.8	41.0
Rotavation + hoeing	18.23	18.11	37.3	33.3
Simazine 2.0 lb + hoeing	21.64	20.87	38.3	38.6
Simazine 2.0 lb + paraquat 0.5 lb/100 gal	18.59	19.94	34.5	36.8
Paraquat 0.5 lb/100 gal	16.31	20.42	33.3	36.8
Simazine 2.0 lb + paraquat 0.5 lb/100 gal + light mulch	19.38	21.29	37.7	38.3
Paraquat 0.5 lb/100 gal	18.02	20.22	32.8	37.8
General mean	20.32	21.35	36.7	38.4
Standard error per plot	3.92	3.96	3.7	3.9
Significance of F test	0.5%	1.0%	0.5%	1.0%

[1] Normal cultivation is the system employing ploughs, draw hoes and light inter-row cultivation commonly practised in Angus and Perthshire.

DISCUSSION

The safety and effectiveness of simazine for annual weed control in raspberries has now been demonstrated at Mylnefield and elsewhere. The herbicide is commonly band-applied on either side of the rows, leaving a central alleyway to be cultivated mechanically to control weeds and suckers. Hand-hoeing is still generally used to destroy surplus suckers actually within the rows, although partially successful attempts have been made to remove these with desiccant chemicals or with mechanical implements.

Before the advent of herbicides it was the usual practice in commercial raspberry growing to draw a shallow furrow towards the rows in winter and again in spring, enabling draw hoes to be used for removing weeds and suckers between the stools in spring and early summer without exposing roots. (This is referred to in Table 3 as "normal cultivation".) Another method is to cultivate the rows entirely with dutch hoes, without drawing any plough furrows, and to use only shallow mechanical cultivation in the alleyways. The latter system is more easily combined with the use of simazine, but workers accustomed to using draw hoes do not easily adapt themselves to a different method of hoeing. The very preliminary results given in Table 3 would seem to suggest that the older method - using plough furrows and draw hoes - is superior, but the figures may merely reflect a reduction in the damage done to young canes by winds as a result of the extra support given during the first year. At this early stage of the experiment no firm conclusion can be drawn on this question, but the results in future years may be of considerable interest.

In the absence of competition from annual weeds, perennial species such as creeping thistle (Cirsium arvense), couch grass (Agropyron repens) and coltsfoot (Tussilago farfara) tend to increase. Creeping buttercup (Ranunculus repens), which also tends to spread, can be controlled by spot spraying with paraquat or paraquat/diquat mixture during the winter, but the other species are merely scorched by these treatments. Atrazine, bromacil and 2,6-dichlorothiobenzamide might be expected to be useful for spot-spraying patches of perennial weeds, and it is of interest that all three compounds when applied overall have given excellent annual weed control without any indication so far of damage to the raspberries. No taints associated with the herbicides used in these experiments have so far been detected in jam samples, but the taint situation, if there is in fact one at all, could be complicated by the routine sprays of insecticides and fungicides which are applied as required directly to the aerial parts of raspberry canes in spring and summer.

Acknowledgments

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THE USE OF 2,6-DICHLOROTHIOBENZAMIDE (W.L.5792) IN TOP AND SOFT FRUIT

H. Sandford
Shell Chemical Company Limited, London

Summary Field trials in top and soft fruit were carried out over a period of three years with wettable powder and granular formulations of 2,6-dichlorothiobenzamide (W.L.5792). Phytotoxicity and persistence of the wettable powder was greatly increased by incorporation with the soil after treatment. Granules were less dependent upon incorporation and good weed control was consistently obtained provided that applications were made in low temperatures and wet conditions in the early spring. Granules at the rate of 4 lb/ac controlled annual weeds and 6 and 10 lb/ac controlled annuals and susceptible perennials for approximately 4 and 6 months respectively. Perennials which most commonly occurred in field trials which were controlled included *Cirsium arvense*, *Urtica dioica*, *Taraxacum officinale* and *Rumex* spp. In replicated experiments yields of pears, apples, black-currants, gooseberries and raspberries were not affected by incorporated treatments of wettable powder. However, in the early autumn of 1964 slight leaf margin chlorosis appeared on all crops except raspberries where the granular formulations had been applied and the cause of these symptoms is still under investigation.

INTRODUCTION

Under field conditions, 2,6-dichlorothiobenzamide (code no. W.L.5792) is broken down to form 2,6-dichlorobenzonitrile (dichlobenil) by microbiological activity in the soil. (Barnsley 1963). Experiments with dichlobenil in top and soft fruit were described at the 6th British Weed Control Conference (Sandford 1962). For consistent results it is necessary to incorporate dichlobenil with the soil to reduce loss of chemical vapour into the atmosphere by volatilization. Soil incorporation with W.L.5792 is not so essential as it is a less volatile compound with a greater water-solubility. Nevertheless, treatments should be applied in the early spring when temperatures are low and natural incorporation by rainfall can be anticipated. Although the action of both compounds is similar, W.L.5792 persists longer in the soil and has a greater phytotoxicity to weeds. (Rosher 1963).

The aims of the field trials with W.L.5792 were to determine optimum dosage rates required to give long-term control of annual and perennial weeds in fruit crops.

METHODS AND MATERIALS

Field trials were carried out during 1962 - 1964 and are divided into the following series:-

Series A. Grower Trials

In 1963 treatments were applied by commercial growers at 32 separate sites, on different soil types. W.L.5792 7½% granules were applied by means of a calibrated polythene dispenser at 6 and 10 lb/ac. W.L.5792 50% wettable powder was applied by tractor operated spraying machines or knapsack sprayers. Treatments were applied to the soil surface without mechanical incorporation in the early spring before or shortly after weed emergence. Crops treated included established apples, pears, plums, cherries, gooseberries, loganberries, redcurrants and blackcurrants. Results were assessed by Shell Chemical Co. technical staff at various intervals after application.

Series B. Replicated Experiments

W.L.5792 granules at concentrations of 7½, 15 and 20% were compared with 50 and 75% wettable powder formulations as surface and incorporated treatments. Experiments were carried out in young and mature top and soft fruit to determine maximum crop tolerance rates and to assess control of annual and perennial weeds. Treatments were applied in the autumn or in the spring. Soil incorporation was carried out by rotavator, rigid tine cultivator or hand-raking immediately after treatment. Granules were broadcast by hand and the wettable powders applied with an Oxford Precision sprayer in volumes of up to 200 gal/ac.

Series C. Treatments applied to established perennial weeds in fruit

W.L.5792 7½% granules were applied at 10 - 35 lb/ac to various species of established perennial weeds in apples, pears, blackcurrants and raspberries. Treatments were applied during the spring or summer and in the majority of the trials there was a dense growth of weeds at the time of application.

In all trials weed control was assessed by three assessors scoring the plots independently.

RESULTS

Effects on weeds

In 12 of the Series A trials, control of annual and perennial weeds was assessed at fortnightly intervals following treatments applied to the soil surface in the early spring. The results of the assessments are shown in Table 1.

Table 1

Number of trial sites at which commercially satisfactory weed control was obtained at two week intervals after application

Formulation	Dose	Number of weeks after treatment 10	12	14	16	18	20	22	24
Wettable powder	6 lb/ac	12	12	12	8	8	7	-	4
" "	10 " "	12	12	12	10	10	9	-	8
Granules	6 " "	12	12	-	11	10	10	-	8
"	10 " "	12	12	12	12	12	12	-	12

The main weed species present in these trials were Agropyron repens, Cirsium arvense, Rumex spp, Urtica dioica and a wide spectrum of annual weeds.

Granules at 10 lb/ac gave satisfactory weed control at every site for 6 months following application. After this period, the more resistant perennial weeds, such as Convolvulus arvensis and Agropyron repens, started to recolonize. Satisfactory control of annuals and susceptible perennials was obtained for 4 months from the application of granules at 6 lb/ac. The wettable powder did not persist for as long as the granules.

Further information on the persistence of granules for the maintenance of long-term weed control was obtained from trials in Series A and C as shown in Table 2. Initial treatments were applied in the early spring of 1963 and in some trials 'follow-up' applications applied 12 months later.

Table 2

Percentage weed control in 8 trials 17 months after initial treatment with granules

Dose of granules unincorporated 1963	1964	Soil Type: Trials on Medium loams					Trials on Sandy loams		Trial on Chalky loam	Mean % weed control
10 lb/ac	nil	-	30	-	0	0	0	0	0	5.0
6 " "	"	-	10	0	0	0	20	0	-	5.0
10 " "	10 lb/ac	-	100	95	95	90	97	100	70	92.5
10 " "	6 " "	-	90	100	95	94	99	85	70	91.9
6 " "	6 " "	100	90	90	70	88	70	95	77	85.0
6 " "	4 " "	100	90	70	-	-	80	70	85	82.5

The results indicate that the effects of treatment persist in the soil for at least 12 months, so that satisfactory long-term control of annual and susceptible perennial weeds can be maintained by following an initial heavy dose with a reduced 'follow-up' treatment in the second year. There were no apparent differences in weed control obtained on the different soil types within the range of textures tested.

The response of weeds commonly occurring in the field trials to doses of granules at 6 - 10 lb/ac was as follows:-

Susceptible or moderately susceptible species

Most annual dicotyledons and monocotyledons. Cirsium arvense, Urtica dioica, Taraxacum officinale, Rumex spp., Tussilago farfara, Pteridium aquilinum, Plantago spp., Equisetum spp., Aegopodium podagraria.

Semi-resistant species (controlled under optimum conditions, e.g. incorporation)

Agropyron repens, Agrostis gigantea, A. stolonifera, Bromus spp., Viola arvensis.

Resistant species (sometimes suppressed under optimum conditions, e.g. incorporation)

Convolvulus arvensis, Hypericum perforatum, Juncus spp., Potentilla spp., Ranunculus spp., Epilobium spp., Cardamine spp., Rubus spp., Trifolium spp., Polygonum convolvulus, and Heracleum sphondylium.

There were wide variations in the response of different species of perennial weeds to W.L.5792. Consequently, treatments applied to mixed stands sometimes resulted in more vigorous growth of the more resistant species due to the removal of plant competition from those weeds which were controlled. In extreme cases, for example, Convolvulus arvensis almost completely covered the plots within 2 - 3 months of treatment.

Granules applied annually for three consecutive years to 5 replicated experiments and incorporated with the soil in Series B gave the results shown in Table 3. The main weed species present included Agropyron repens, Agrostis spp., Convolvulus arvensis and most of the common annual weeds.

Table 3

Effect of annual applications of granules on weeds

Dose	Time of first Application (repeated annually)	Per cent weed cover and date of assessment: July '62	July '63	May '64
4 lb/ac	Nov. 1961	55	65	35
"	April 1962	30	30	15
8 "	Nov. 1961	75	20	10
"	April 1962	20	10	10
16 "	Nov. 1961	60	10	0
"	April 1962	10	0	0
Control (hand weeded)		65	90	85
Means		43	22	12

Treatments applied in April of each year reduced the weed cover by 63% compared with November applications. A wide spectrum of annual and perennial weeds was controlled and there was a progressive improvement in weed control obtained, indicating that satisfactory control can be maintained by reduced doses in successive years.

Wettable powders applied to the soil surface gave very variable weed confrol in the absence of incorporation. When rain fell within a few hours of spraying good control of annual weeds and some suppression of perennials was obtained but under dry conditions results were frequently unsatisfactory due to loss of chemical into the atmosphere by volatilization. In the replicated trials, unincorporated treatments of wettable powder also gave variable results depending upon the weather conditions after spraying, and in all trials the degree of weed control and persistence in the soil of surface applications was less than that of the granular formulation.

Granules applied in the early spring consistently gave good results without incorporation. Nevertheless, for optimum control of weeds performance was improved when wet weather and low temperatures followed application. In a few trials applied under less than optimum conditions, perennial weeds, treated with granules at 8 - 10 lb/ac started to regenerate in the autumn. In these trials, regeneration proceeded rapidly once the chemical barrier in the topsoil had started to break down.

Although granules applied before the start of active spring growth gave good weed control, later applications in April and May did not consistently do so, due to volatilization of the chemical in warmer, drier conditions. Mid-summer treatments of granules at 10 - 15 lb/ac to dense stands of established perennial weeds in Series C trials generally gave good control, thought to be due to the preservation of a blanket of vapour at the soil surface by the foliage canopy.

In the trials in Series B, concentrations of 7½, 15 and 20% granules were compared. The granules were broadcast by hand or distributed by means of a polythene sprinkler. Areas treated were traversed at least twice from different directions. Uniform distribution was obtained only with the 7½% concentration, the 15 and 20% concentrations resulted in patchy weed control.

Effect on crops

Apples A randomized block experiment with 3 replicates was carried out on Worcester apples grown on a medium loam soil. Wettable powder and granules were applied at 3 doses in the autumn of 1961 and spring of 1962 and incorporated by rotavation. The same treatments were repeated in 1962/63. Plot size was $800ft^2$ with 2 trees per plot. The results are shown in Table 4.

Table 4

Effect of wettable powder and granules on apples

Dose	Formulation	Time of Application	Mean yields in cwt/ac 1962	1963
4 lb/ac	spray	Spring	174.3	220.3
"	granules	"	150.7	179.5
"	spray	Autumn	-	175.3
"	granules	"	-	145.1
8 lb/ac	spray	Spring	158.8	213.8
"	granules	"	186.7	209.0
"	spray	Autumn	-	219.8
"	granules	"	-	192.9
16 lb/ac	spray	Spring	185.6	170.5
"	granules	"	158.8	194.4
"	spray	Autumn	-	220.3
"	granules	"	-	178.8
Control (hand weeded)			154.9	186.1
Sig. diff. (P = 0.01)			-	45.1

There are no significant differences between the mean dosage rates of spray and granules or between autumn and spring applications.

Gooseberries A randomized block experiment with 5 replicates was carried out on Careless gooseberries. Three doses of wettable powder were applied in the spring of 1962 and 1963 and incorporated with the soil by shallow rotavation. Plot size was 250ft^2 with 10 bushes per plot.

Table 5

Effect of wettable powder on gooseberries over 2 years

Dose	Mean yield in cwt/ac 1962	1963	Mean yields of two years
1 lb/ac	38.7	33.6	36.1
2 "	33.3	42.6	37.9
4 "	34.5	44.8	39.6
Control (hand weeded)	27.1	34.4	30.7
Sig. diff. (P = 0.05)	N.S.	8.3	N.S.
S.E.	3.6	-	2.6

All chemical treatments gave an increase in the mean yield over two years, although the difference is not significant.

Blackcurrants Wettable powder at 3 dosage rates was applied to Baldwin blackcurrants in the autumn or the spring for three consecutive years. Treatments were incorporated by shallow rotavation. The experiment was a randomized block design with 4 replicates. Plot size was 405ft^2 with 10 bushes per plot.

Table 6

Effect of wettable powder on blackcurrants over 3 years

Dose	Time of Application	Mean yield in cwt/ac 1962	1963	1964	Mean yields of 1962 and 1963
2 lb/ac	Autumn	29.0	36.1	35.3	32.5
"	Spring	25.4	34.6	36.4	30.0
4 "	Autumn	25.0	38.2	22.3	26.6
"	Spring	34.8	47.5	41.8	41.1
8 "	Autumn	27.5	37.2	37.7	32.3
"	Spring	35.3	48.7	36.5	42.0
Control (hand weeded)		26.2	25.2	30.0	25.7
Sig.diff (P = 0.05)		N.S.	15.8	N.S.	4.8
S.E.		2.2	-	2.6	-

Over three years all treatments gave an increase in mean yield over the hand weeded control.

Raspberries Wettable powder at 3 doses was applied to Norfolk Giant raspberries in the autumn or the spring for three consecutive years. Treatments were incorporated with the soil by shallow rotavation. The experiment was a randomized block design with 4 replications. Plot size was 180ft^2.

Table 7

Effect of wettable powder on raspberries over 3 years

Dose	Time of Application	Mean yield in cwt/ac 1962	1963	1964	Mean yields of three years
1 lb/ac	Autumn	53.0	82.4	59.5	65.0
"	Spring	39.8	58.7	51.9	50.1
2 "	Autumn	51.7	82.5	72.5	68.9
"	Spring	55.0	78.8	66.0	66.6
4 "	Autumn	53.1	82.3	66.0	67.1
"	Spring	54.2	70.1	55.7	60.0
Control (hand weeded)		58.8	77.5	68.7	68.3
Sig.diff (P = 0.05)		11.1	N.S.	-	15.6
S.E.		-	3.8	-	-

Owing to a number of missing plots the results for 1964 cannot be analysed. The significant reduction in yield at 1 lb/ac applied in the spring of 1962 appears to be a coincidence since higher rates have caused no ill effects.

During 1962 - 1964, many non-replicated trials were carried out and in addition, limited quantities of 7½% granules were marketed on a development basis in 1964. Treatments were applied at doses of up to 10 lb/ac to apples and pears established for at least one year and to blackcurrants, redcurrants and gooseberries established for at least two years. Granules were also applied for the control of annual weeds in established fruiting crops of raspberries, loganberries, plums and cherries at a dosage rate of 4 lb/ac. The control of annual and susceptible perennial weeds in these trials and commercial applications was good, but in a few cases, particularly on light soils, slight phytotoxicity was noted on apples, pears, plums and gooseberries. Symptoms took the form of marginal chlorosis of the older leaves, leaves of the current year's growth being unaffected. In a few cases, particularly in young fruit on the lighter soil types, leaf margins became necrotic and the chlorosis spread intravenally. There was no apparent effect on crop yields. Plums were more severly affected than other crops and pears appeared to be more susceptible than apples.

In trials where simazine was applied at rates of 1 - 2 lb/ac for the control of annual weeds, the addition of W.L.5792 granules increased the severity of the symptoms.

There were no indications that crop yields were affected but a full investigation into the cause of these symptoms is being undertaken. Soil and leaf samples will be analysed for chemical residues and nutritional status and field trials w ill be continued in 1965.

DISCUSSION

For the control of annual weeds in top and soft fruit, simazine has been used extensively for a number of years. Perennials are not controlled however, with the result that many orchards have become infested with these weeds. Experiments carried out since 1962 show that W.L.5792 will control many perennials in addition to annuals.

W.L.5792 wettable powder applied to the soil surface did not give as satisfactory long-term weed control as granules, presumably owing to volatilization of the chemical in the absence of rainfall after application. To ensure consistent results incorporation of the wettable powder by rainfall, irrigation or mechanical cultivation is necessary, but even when treatments are applied in the early spring, rainfall is frequently unpredictable and irrigation or mechanical incorporation not always convenient to the grower. The granular formulation is less dependent upon incorporation and is therefore to be preferred.

The results of the trials indicate that for the control of annual and susceptible perennial weeds throughout the growing season, granules at 10 lb/ac or wettable powder at 13 lb/ac should be applied. Some growers prefer a vegetative cover around the base of fruit trees during harvest to facilitate picking and, in this case, doses should be reduced to granules at 7 lb/ac and wettable powder to 9 lb/ac to give weed control for about 4 months. For the control of annuals and some suppression of perennials, granules at 4 lb/ac or wettable powder at 5 lb/ac is required. The optimum time of application is in the early spring when temperatures are low and rainfall can generally be anticipated. Treatments applied later in the year have given promising results when the chemical has been incorporated with the soil by mechanical means or overhead irrigation.

A large number of field trials have been carried out over a period of 5 years with dichlobenil and with W.L.5792, which is converted to dichlobenil in the soil, for 3 years. During this lengthy experimental period, no adverse effects on fruit crops were observed until the early autumn of 1964 when in some trials on pears, apples, plums, blackcurrants and gooseberries, slight symptoms of leaf margin chlorosis were observed. Despite this, yields of crops in the replicated experiments, in which these symptoms appeared, were not adversely affected.

A full investigation into the cause of this phytotoxicity is being undertaken. A possible cause is the unusual weather conditions experienced during 1964. In the spring, when the treatments were applied, rainfall was heavy and this tended to leach the chemical downwards, especially on light soils low in organic matter. There followed a very dry period in July and August when soil moisture status fell to a very low level. Phytotoxic symptoms at rates of 6 - 10 lb/ac are thought to be related to the moisture stress associated with these dry conditions. Confirmation of this hypothesis is still under investigation.

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TRIAZINES IN TOP FRUIT AND VITICULTURE

A. Gast and J. Grob
J.R. Geigy S.A., Basle (Switzerland)

Summary Treatments with simazine and atrazine in fruit orchards and vineyards cause growth stimulations and yield increase, which cannot be attributed alone to the destruction of the weed vegetation, i. e. the removal of the nutrient competition. Analytical data shows an increased nitrogen content in the leaves of treated plants. simazine or atrazine applications result in a "fertilizer effect" which may be caused by a change in the nitrogen metabolism and/or increased nitrogen uptake by the treated plants.

INTRODUCTION

The use of triazines alone, or in mixtures with other herbicides, has developed into a common practice in several countries. simazine is the most profitable substance at present as regards its herbicidal activity and crop tolerance. In certain situations atrazine has a superior herbicidal effect to simazine, but the tolerance shown by crops is somewhat lower. In Switzerland for example simazine is recommended for the general treatment of fruit orchards and vineyards. Atrazine is used only in vineyards with Convolvulus arvensis as the dominant weed, since this species is not effectively controlled by simazine. In other countries mixtures of simazine and amitrole are mainly advised for use in fruit orchards.

Even in the first few years of our work with triazine herbicides it appeared remarkable that maize reacted to a simazine treatment with a strong stimulation and a dark green colour. Gast et al (1960) reported much higher yields and a remarkable increase of the raw proteins in this crop after treatments with simazine and atrazine. On grapes and fruittrees similar effects were also noted. For instance simazine treated grapes developed greener and in some cases larger leaves than untreated plants, in addition shoot growth was also stimulated. In autumn the leaves of grapes treated with simazine remained green longer and dropped off later (Gast 1960).

It was the aim of a series of experiments carried out and observed over a period of several years to gain more information on growth stimulation and "greening effect" in fruit orchards and vineyards produced by triazine treatments.

Experiment 1

In this experiment different grape root-stocks were cultivated in a garden frame. After planting of the root-stocks simazine and atrazine were applied on the soil surface. As all growing weeds were eliminated by hand weeding, a competition effect in the check plot was excluded.

In Fig. 1 the shoot growth at the end of the first vegetation period is demonstrated. Depending on the variety and dosage rate of the herbicide used, the growth ratio of the treated root-stocks is stimulated to a greater or lesser extent.

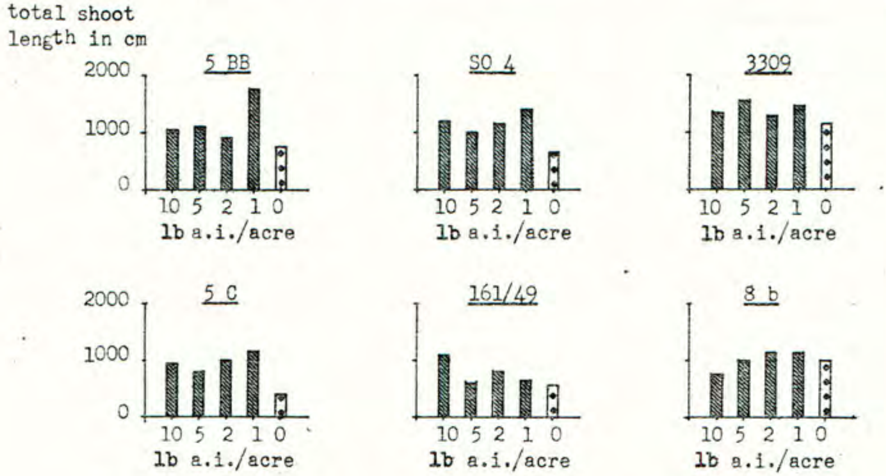

Fig.1 Shoot length of grape root-stocks treated with simazine (10 plants per variety)

In a corresponding treatment instead of simazine atrazine was applied, giving a fundamentally similar effect (Fig. 2).

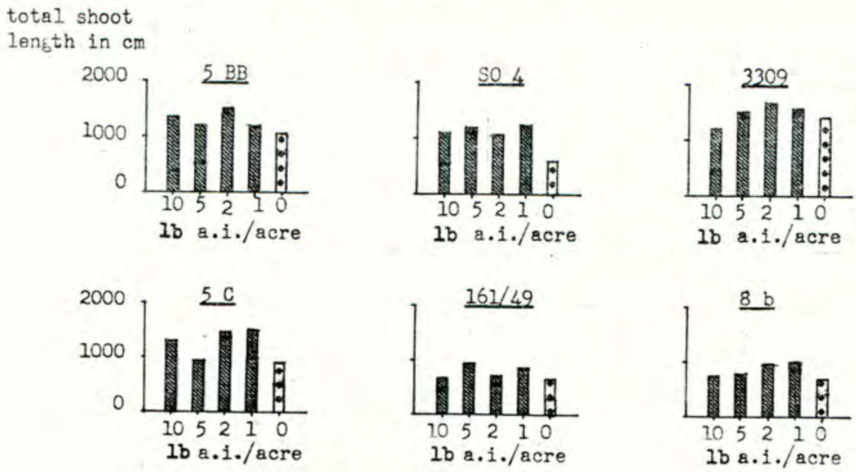

Fig.2 Shoot length of grape root-stocks treated with atrazine (10 plants per variety)

It is of interest that the stimulating effect of the treatments remained visible a year after the herbicide application.

Experiment 2

A fruit orchard with different varieties was treated in 1956, 1957 and 1958 with 10 lbs a. i./ac and 5 lbs a. i./ac of simazine respectively. Two groups of check plots were left without chemical treatments; one of these was mechanically weeded, the other was left unweeded. The main weed in this orchard was *Agropyron repens*.

Table 1 gives a compilation of the measurements of shoot length and stem size at the end of 1958. A general comparison of the shoot length in the simazine treated plots with the check plots shows a remarkable increase of the shoot growth in all simazine treated plots. The growth increase of the simazine treated trees is especially large if compared with the unweeded check plots, but the difference is still quite remarkable in comparison to the weeded plots. These facts indicate that the growth stimulation is not only due to the removal of the competing weed vegetation but also to a direct influence of the chemical on the growth of the tree.

Experiment 3

The results of treatment of "Golden Delicious" with simazine and atrazine over a period of three years (1960, 1961, 1962) are given in Fig. 3. All shoots were measured and classified according to their length. The chemical treatments result in a greater number of longer shoots if compared with the check trees.

The development of the stem diameters is given in the following table.

Table 2 % increase of stem diameters

	1960/1961	1961/1962
Check	29	26
Simazine	39	41
Atrazine	45	43

Experiment 4

This experiment includes a series of simazine and atrazine treatments on grapes repeated over a period of several years. All the treatments were made in 10-15 year old grape vines of the variety "Chasselas". The first group of treatments was started 1956 and each treatment was repeated in each ensuing year; up to and including 1963 the plots got 8 treatments. Yield records were taken since 1958 (Fig. 4). Another group of treatments was started 1958 (Fig. 5) and a third one 1959 (Fig. 6).

variety	Simazine 3x10 lbs a.i./acre						Simazine 3x5 lbs a.i./acre						untreated				
	Av. Shoot length per tree in cm	Av. Shoot length ± % of untreated		Circumference in cm (weeded)		% increase in about 1 year	Av. Shoot length per tree in cm	Av. Shoot length ± % of untreated		Circumference in cm (weeded)		% increase in about 1 year	Av. Shoot length per tree in cm		Circumference in cm		% increase in about 1 year
		weeded	without weeding	1957	1958			weeded	without weeding	1957	1958		weeded	without weeding	1957	1958	
Canada R. (Bush)	23610	+44	+171	57.5	61.4	+6.8	27630	+68	+218	60.5	64.8	+7.1	16395	8690	57.6	57.6	±0
Canada R. (Tree)	13500		+167	51.5	55.0	+6.8	28010		+349	62.0	65.0	+4.8		6230	61.3	62.7	+2.2
Cox Orange (Bush)	28550	+132	+456	32.0	36.5	+14.0	31240	+154	+508	47.0	50.2	+6.8	12290	5130	41.7	41.7	± 0
Champagner R. (Bush)	5740	+45	+338	35.3	37.3	+5.6	8095	+104	+517	25.5	30.0	+17.6	3950	1310	34.3	34.3	± 0
Starking (Bush)	15880		+782											1800			
Gold-parmäne							20440		+987					1880			
Winter-banane							6040		+62					3720			

Table 1 Shoot length of different apple varieties after 3 years of treatments with Simazine
(Treatment with 3x10 kg a.i. and 3x5 kg a.i./acre respectively in the years 1956, 1957 and 1958, measured 1958)

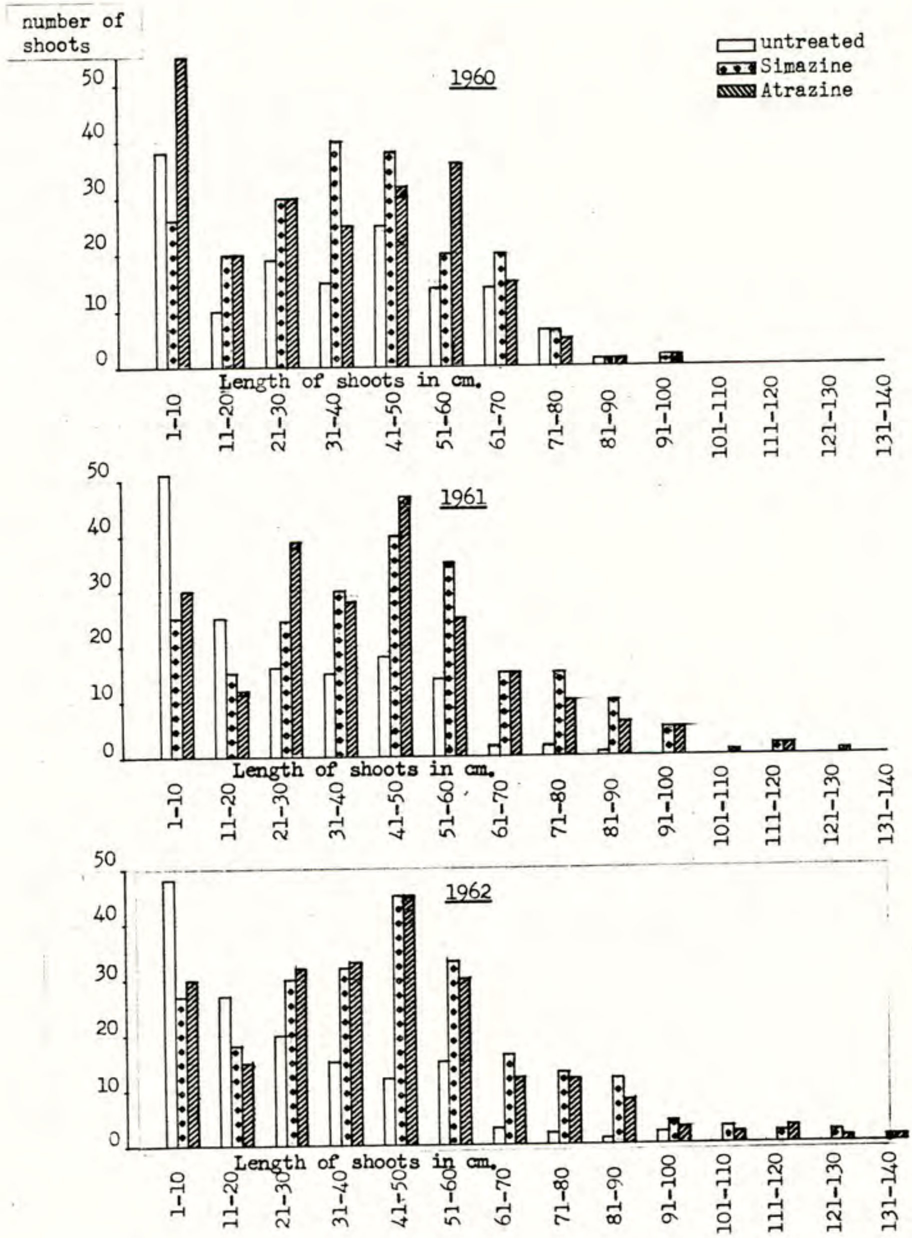

Fig.3 Shoot growth of Golden Delicious treated during three years with Simazine and Atrazine, each 5 lbs a.i./acre

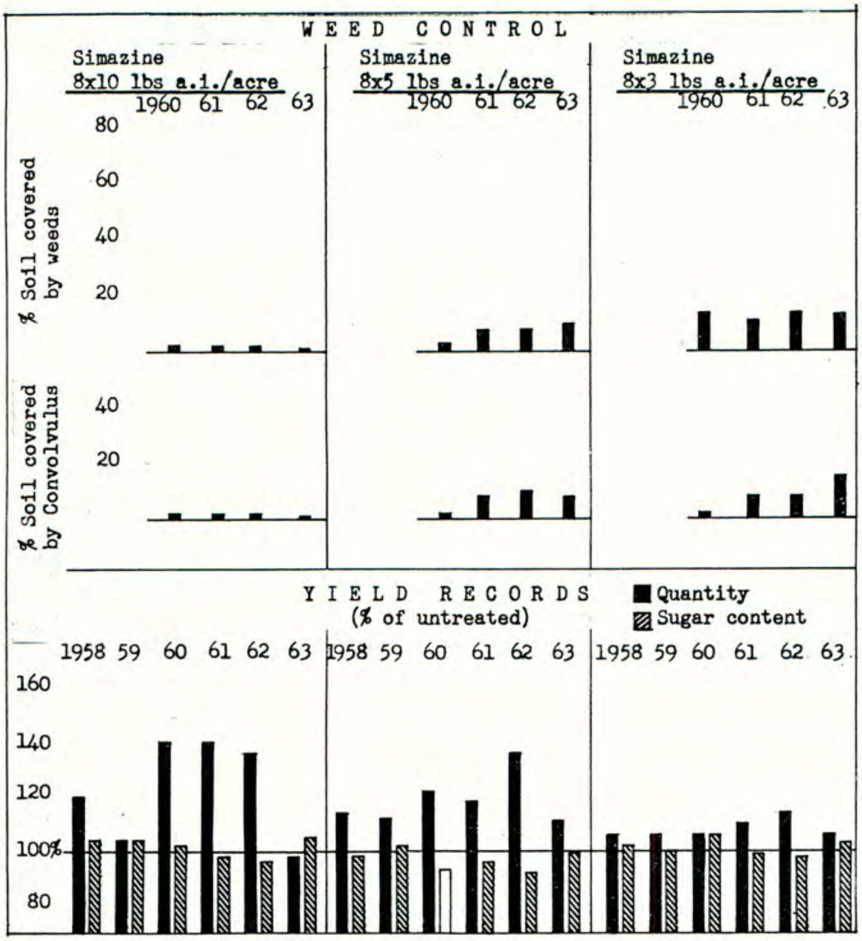

Fig.4 Effect of repeated Simazine treatments started 1956 in Fully (Rhone Valley)

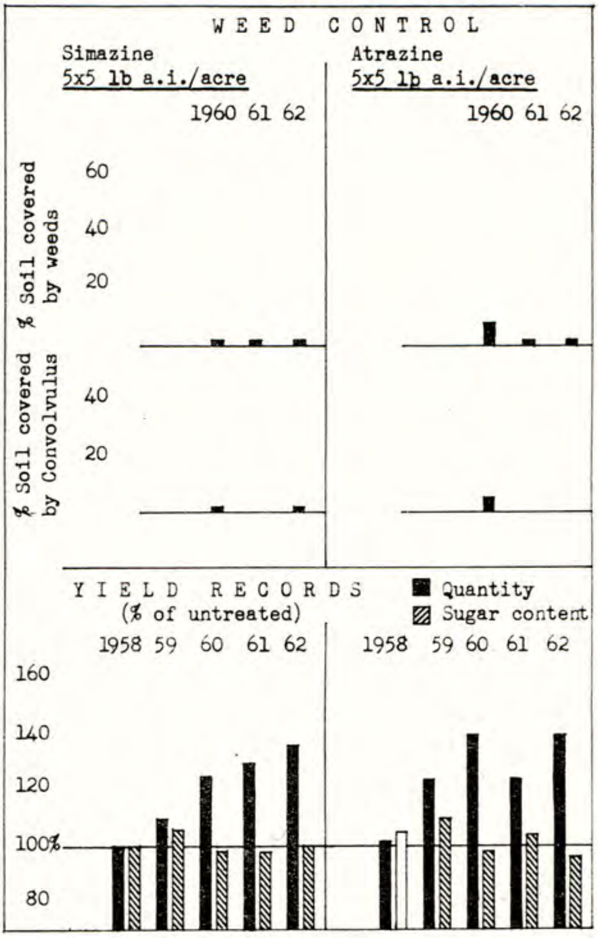

Fig.5 Effect of repeated Simazine and Atrazine treatments started 1958 in Fully (Rhone Valley)

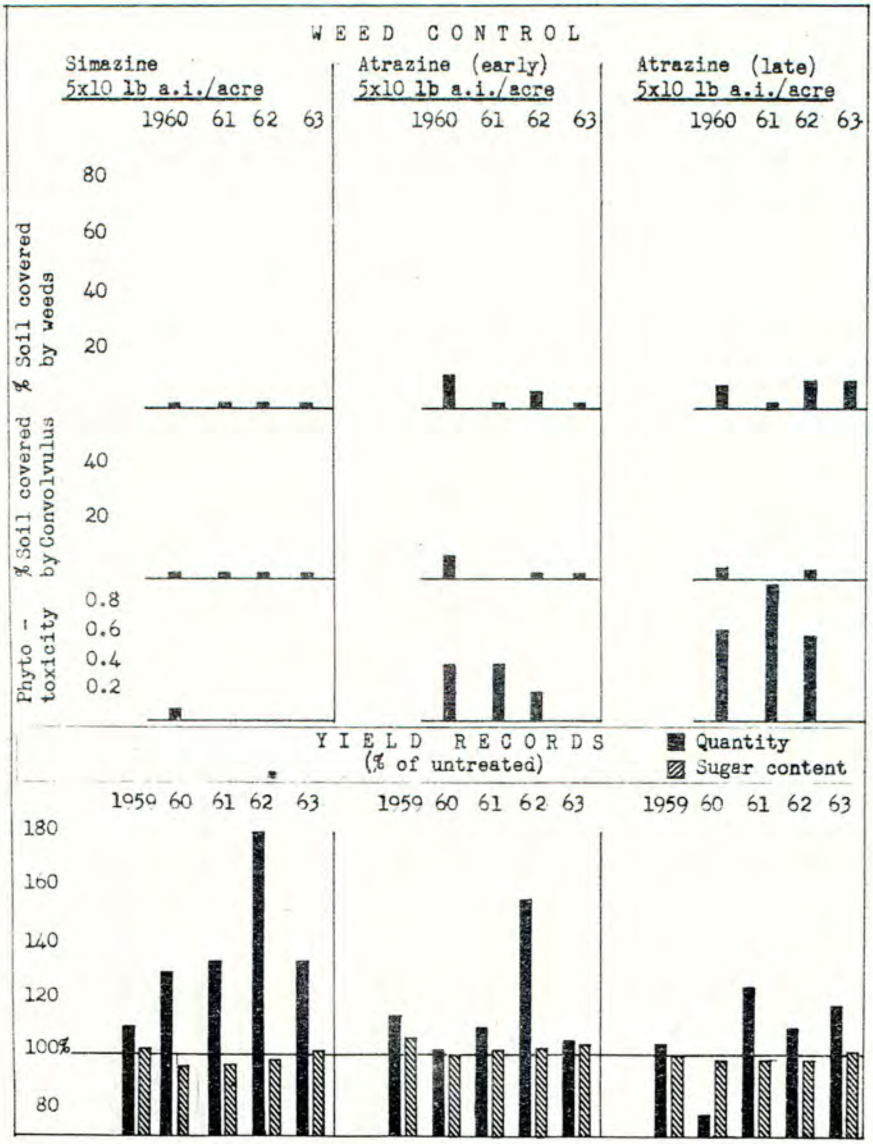

Fig. 6 Effect of repeated Simazine and Atrazine treatments started 1959 in Fully (Rhone Valley)

The treatments started in 1956 compare three dosage rates of simazine (Fig. 4). A comparison of the yield records shows that the highest yield increase was obtained in the plots treated with 10 lbs a.i. simazine. The lowest increase was found in the 3 lbs plots, where a very reduced weed vegetation of mainly Convolvulus arvensis remained. Therefore, a certain influence of this weed vegetation cannot be completely excluded; however this alone is probably insufficient to account for the reduced yield increase. In the 5 lbs plots although nearly the same amount of weeds remained, a remarkable increase on the yield compared with the 3 lbs plots was evident. We are inclined to think of a direct influence of the higher dosage rate of simazine on the grape plant.

Fig. 5 shows that atrazine is able to produce a similar yield increase to simazine.

The results of the treatments started 1959 (Fig. 6) allow an interesting comparison of the effects of simazine and atrazine. Simazine produced high yields in all years whereas atrazine gave some phytotoxicity symptoms, i.e. various degrees of chlorosis. It is of importance that in spite of the chlorosis there was still a certain increase in the yields (with one exception, late treatment of atrazine 1960). There is another striking fact, the sugar content remained practically at the same level as in the check plots.

DISCUSSION

These findings give evidence that treatments with simazine and to a certain extent also with atrazine in fruit orchards and vineyards result in a growth stimulation and yield increase. These facts cannot be attributed solely to the destruction of the original weed vegetation, a very potent nutrient competitor. In experiment 1 the plants were cultivated in a weed free environment and in experiment 2 the simazine treated plots remained superior to the mechanically weeded plots. Furthermore in the grape experiments it is hard to believe that the occasional high yield increases should be purely due to the removal of the nutrient competitors alone.

"Greening effects" and yield increase on grapes were already reported by Gast (1960). Mohs (1961) found that root-stocks of apples, grown in water cultures in a greenhouse, showed an increased shoot growth when simazine was added to the nutrient liquid.

A lot of data in regard to growth stimulation and yield increase of fruit trees was reported by Karnatz (1964). He comes to the conclusion that the growth reactions are so large that they cannot be attributed to the removal of the weed competition alone. In some experiments he found the "fertilizing effect" of simazine to be superior to the effect of a special nitrogen fertilization. Leaf analysis of simazine treated trees showed a nitrogen increase of about 20% over the nitrogen content of untreated leaves. Similar results are reported by Ries et al (1963) on peach trees. In his experiments the chemical treatments (simazine + amitrole T) were compared with plots in which the weeds were destroyed mechanically or where the weed growth was prevented by a cover of black plastic sheets. The reaction of the peach trees is similar to that of apple trees, i.e. increased shoot growth and higher nitrogen content of the leaves. It is of interest that Ries could not find an increased nitrogen content of the soil.

It is still an open question how the "fertilizing effect" of triazines can be explained. It seems that changes in the nitrification or of the nitrogen uptake by the roots could be possible explanations of these striking growth reactions.

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POT EXPERIMENTS ON SUSCEPTIBILITY OF PERENNIAL CROPS TO SOIL APPLIED HERBICIDES

G.W. Ivens

A.R.C. Weed Research Organisation,
Begbroke Hill, Oxford.

Summary A series of trials is described in which the response has been determined of a range of perennial horticultural crops transplanted into pots containing mixtures of soil and various soil-applied herbicides. Under these conditions strawberries and seedling *Rosa canina* and *R. laxa* were found to be less resistant to atrazine than simazine. Strawberries showed considerable resistance to trietazine, chloroxuron and diphenamid and the two rose species to linuron and prometryne. Anemones appeared to possess little resistance to simazine, a small degree of resistance to fenuron and greater tolerance to chlorpropham, linuron, chloramben and chloroxuron. The relative resistance to simazine of the various species tested is in general agreement with results obtained in the field, which is taken as evidence that depth-protection is not always the dominant factor in determining the resistance of perennial plants. There is evidence that the size of the plant has an important influence on its response in trials of this type.

INTRODUCTION

The factor of depth-protection is thought to play a large part in the selectivity of soil-applied herbicides in fruit and other perennial crops, most of which have a large proportion of their roots deeper in the soil than the levels normally penetrated by the chemical. Under exceptional conditions of rainfall, soil type or cultivation, however, deeper penetration of chemical may take place and the crop may be damaged. Where soil conditions limit the depth of rooting or where surface rooting is encouraged by non-cultivation, with or without mulching, the chance of chemical being taken up by the crop plant, and thus the chance of injury, is also increased. In order to assess the danger of causing damage and so that recommendations can take such exceptional conditions into account, information is needed on the susceptibility of perennial crops to soil-applied herbicides when the roots are known to be in contact with the chemical and depth-protection no longer operates. Apart from the work of Caseley (1960) few experiments of this type with perennial plants have been reported. An investigation has therefore been started with a number of chemicals at the Weed Research Organisation to obtain basic information on the inherent susceptibility of a range of crops. The aim of the present paper is to report the progress made in this investigation and to discuss some of the factors which can influence the results of pot trials with perennial plants.

METHOD AND MATERIALS

The plant material used in these trials was mostly grown at Begbroke by normal methods: strawberries from runners, raspberries from root-suckers, blackcurrants from stem cuttings, apple rootstocks from stoolbeds and rose rootstocks (R. canina and R. laxa) from 1-year-old seedlings. The plants were grown in various ways until well rooted and then transferred to 8½ in. diameter plastic or 10 in. diameter bitumenised clay pots containing treated soil. In most cases, the chemical was applied to the surface of the soil in the pot before planting, soil and chemical were then thoroughly mixed and the pot refilled. Where surface treatment was used, the calculated quantity of chemical was applied to a thin (0.25 in.) layer of soil in a tin lid, mixed with the soil and then spread evenly over the surface of the soil in the pot after planting. In this way interception of spray by the plant was prevented. Sprays were applied with the special sprayer used for all pot spraying work at Begbroke, in which the spray unit is moved mechanically at constant speed over the pots. In the trial in which activated charcoal was tested, Harrison Clark's steam activated charcoal was employed.

The soil used was the standard alluvial light loam with 3.1% organic matter content as used for screening work with soil-applied herbicides. Mechanical analysis shows 33% coarse sand, 43% fine sand, 11% silt, and 13% clay.

After applying the treatment, the pots were kept in the glasshouse and the effects assessed at intervals. The speed with which effects developed varied according to the species, the chemical, and the time of year at which it was applied. It was normally found that symptoms of injury appeared initially both with sub-lethal and lethal doses, but that plants treated with sub-lethal doses subsequently recovered, while more severely injured plants died. With the numbers of plants used it was not possible to calculate true LD_{50} doses. The critical dose, however, and that which appeared to provide the most sensitive basis for comparison, was the dose level below which normal growth was resumed, but above which progressive deterioration took place. This dose has been assessed by interpolation from graphical expressions of the results and is referred to as the estimated LD_{50}.

RESULTS

Strawberries

(a) Comparison of chemicals. In a trial started in August 1963, runners of Cambridge Favourite with 2-3 expanded leaves, which had been growing in 5 in. pots for a month, were transplanted to 8½in. pots containing soil in which various doses of simazine, atrazine, trietazine, chloroxuron and diphenamid had been mixed. The original soil was shaken from the roots of the plants before planting into the treated soil. There were three replicates of each treatment and the effects after various intervals are shown in table 1.

It is clear that, although some of the more damaging treatments killed the plants by November, slow growth during the winter was accompanied by slow development of herbicide injury and the full effects did not appear until early spring. There was little alteration in the

Table 1
Effects of 5 herbicides on Cambridge Favourite strawberries transplanted into treated soil in August 1963.

Chemical	Dose		Effect on plants at different intervals after treatment				
	lb/ac. mixed to 4in	mg/l. soil (ppm)	Nov. 1963 $2\frac{1}{2}$ months		Feb. 1964 $5\frac{1}{2}$ months	June 1964 $9\frac{1}{2}$ months	
			mean no leaves	% dead leaves	mean no leaves	mean no leaves	mean fr. wt. shoot(g)
Simazine	1	1.1	10	13	16	20	86
"	2	2.2	7	29	8	12	53
"	4	4.4	6	100	0	0	0
Atrazine	0.5	0.5	9	11	13	25	85
"	1	1.1	8	39	7	11	50
"	2	2.2	6	100	0	0	0
Trietazine*	1	1.1	9	27	14	22	86
"	2	2.2	9	22	12	26	82
"	4	4.4	8	17	12	24	94
Chloroxuron	4	4.4	9	11	14	20	82
"	8	8.7	9	19	13	22	88
"	16	17.4	9	18	13	23	87
Diphenamid	2	2.2	8	34	10	19	77
"	4	4.4	8	32	9	16	63
"	8	8.7	8	41	7	9	47
Control	-	-	9	18	14	23	84

relative effects of the treatments between February and June, however, and 6 months is probably long enough for the full effects of herbicides on strawberries to become apparent in this type of trial. The results show that strawberries will tolerate only about half as much atrazine as simazine, but at least twice as much trietazine. Chloroxuron had no effect up to the highest dose tested. The effect of diphenamid was different from that of the triazines, in that it caused very little chlorosis or necrosis of the foliage. Leaves of diphenamid treated plants, however, appeared to age more quickly than untreated and, with the higher concentrations, tended to develop a reddish colouration. Growth was definitely reduced with the highest dose and probably reduced slightly by the medium dose also.

(b) Time of year. Simazine has been tested at various times of year and varying susceptibility has been found. For example, in a preliminary trial started in May on Cambridge Favourite, the effects of simazine developed much more quickly than in the trial described above. With a dose of 3.3 mg/l of soil (equivalent to 3 lb/ac mixed to a depth of 4 in.) the plants were severely damaged after a month. After 3 months one out of three plants was dead, but after 6 months the surviving plants, although reduced in size, were growing normally. With 1.7 mg/l of soil there were never more than slight effects and growth was not reduced.

As shown in Table 2, the estimated LD_{50} dose in this trial is higher than in the one started in August, in spite of the fact that the reaction to simazine was more rapid. It is possible that the difference may be partly connected with the smaller degree of root disturbance in the trial started in May, the plants in this case being transplanted complete with the original ball of soil. However, there are indications from a trial on blackcurrants that root disturbance does not necessarily make plants more susceptible to injury. Table 2 also gives estimates of LD_{50} doses for two other trials in which simazine was applied to the surface of the soil. Here again, larger doses were required to produce injury when the trial was started during a period of rapid growth (no effect with 2 lb/ac) than in winter. However, the comparison is again complicated by the fact that the plants for the winter trial suffered more root disturbance (in this case transplanted direct from the runner bed) than those treated in spring.

(c) Effect of charcoal. In the trial started in December 1963 with runners transplanted from runner beds direct into pots and treated on the soil surface with simazine, a comparison was made between plants with their roots dipped into activated charcoal before planting and those without. Doses of 1, 2 and 4 lb/ac were applied, but the plants showed no signs of damage with any dose until rapid growth started in April. Thereafter, effects developed rapidly and plants treated with 4 lb/ac died, those protected with charcoal somewhat more slowly than the unprotected. With 2 lb/ac also, the unprotected plants were severely injured or killed, while those treated with charcoal were moderately affected and growth was reduced by approximately 50%. With 1 lb/ac, slight injury (followed by recovery) developed without charcoal, whereas there was no obvious effect with charcoal. The final effect on LD_{50} dose is given in Table 2.

Other Fruit Crops

Preliminary estimates of LD_{50} for simazine have been made with raspberry and apple rootstocks and are given in Table 2. With raspberry two trials were conducted under very similar growing conditions and very different results were obtained by treating plants of different sizes. The larger and more resistant plants were grown in 5 in. pots through the preceding summer and winter before being transplanted to treated soil in April. At this time they had vigorous shoots 18 - 24 in. high, in contrast with the more sensitive plants which had only been established in pots for 3 months and were up to 3.5 in. high.

The apples were rooted stools cut from a stoolbed in April, planted direct into treated soil and the shoot cut back to 6 in. above soil level.

Ornamental Crops

Estimates of LD_{50} for simazine similar to those on fruit crops have been made for Rosa canina and Rosa laxa rootstocks and these are included in Table 2. The plants in this trial were planted as 1-year-old seedlings in 5 in. pots in March and transplanted to treated soil in August, the new

Table 2.
Estimated LD_{50} doses for simazine in a series of pot trials with various perennial crop plants.

Crop and period of trial	Incorporated mg/l. of soil (ppm)	Incorporated Equivalent lb/ac mixed to 4 in.	Surface lb/ac
STRAWBERRY (Cambridge Favourite)			
Aug. 1963 - Feb. 1964	2.2	2.0	-
May. 1963 - Nov. 1963	2.2-3.3	2-3	>2
Dec. 1963 - Jun. 1964	-	-	1.5
Dec. 1963 - Jun. 1964 (+charcoal)	-	-	2.0
RASPBERRY (Malling Jewel)			
Apr. 1963 - Aug. 1964 (large plants)	3.6	3.2	4-5
Jul. 1964 - Sep. 1964 (small plants)	1.1	1.0	-
APPLE (M.II rootstock)			
Apr. 1963 - Dec. 1963	5.4-7.2	4.8-6.4	5.0
ROSA CANINA			
Aug. 1963 - Aug. 1964	>5.5	>5	-
ROSA LAXA			
Aug. 1963 - Aug. 1964	>5.5	>5	-
ANEMONE (mixed De Caen & St Brigid var.)			
Feb. 1964 - Jun. 1964	<1.5	<1.3	-

shoots being cut back to 3 buds, any roots growing through the bottom of the pot trimmed off and the roots washed free of soil. The results with various other chemicals applied in the same way are shown in table 3. Simazine at 5 lb/ac (mixed in a 4 in. layer of soil) caused slight necrosis of the foliage of both species at one month after treatment, but growth was not reduced. Linuron at up to 4 lb/ac had no effect at any time. Atrazine 2 lb/ac caused moderate damage initially and permanently reduced growth, while 4 lb/ac caused death or severe damage. With prometryne, only the 8 lb/ac dose caused damage, R. laxa being completely defoliated in a month and R. canina partly so. Later, hower, R. laxa recovered completely, while R. canina died.

Anemones have also been tested in pot trials and, as shown in Table 2, appear to have only a low tolerance to simazine. With fenuron there was considerable damage at 2 lb/ac and little at 1 lb/ac. Chloroxuron caused damage at 16 lb/ac, but not at 8 lb/ac, while linuron, chloramben and chlorpropham caused no obvious injury at 4 lb/ac.

Table 3.
Effects of 4 herbicides on second year Rosa canina and R. laxa seedlings transplanted into treated soil in August 1963.

Chemical	Dose lb/ac mixed to 4 in	Dose mg/l. soil (ppm)	Total fresh weight in August 1964 as percentage of control (mean of 3 replicates) Rosa canina	Rosa laxa
Simazine	0.6	0.7	75	122
"	1.2	1.3	82	110
"	2.5	2.7	90	105
"	5.0	5.4	104	106
Atrazine	0.5	0.5	103	96
"	1.0	1.1	106	81
"	2.0	2.2	67	77
"	4.0	4.4	0	21
Prometryne	1.0	1.1	77	99
"	2.0	2.2	75	111
"	4.0	4.4	89	117
"	8.0	8.7	0	109
Linuron	0.5	0.5	91	108
"	1.0	1.1	92	91
"	2.0	2.2	105	112
"	4.0	4.4	95	110

DISCUSSION

The results obtained in this series of experiments suggest that trials with plants in pots can give a useful indication of the relative tolerance of perennial crops to soil-applied herbicides in the field. With strawberry, for example, the relative tolerance to the various chemicals tested (less tolerance to atrazine than to simazine and more to trietazine, chloroxuron and diphenamid) is very much in line with the results of field trials (Ivens 1962, Loughgall 1962, Campbell & Singh 1962). With anemones, tolerance to simazine is shown to be low, so that injury would be expected under conditions favouring deep penetration into the soil. This is another finding borne out by field experiments (Rosewarne 1962). There is somewhat higher, though limited, tolerance to fenuron, the other chemical often used in anemones (normally mixed with chlorpropham), but the margin of safety would appear to be small. Tolerance towards linuron, chloramben and chloroxuron was relatively high in the present trial and these chemicals appear to warrant further testing under field conditions.

The results are also in general agreement with those of field trials as regards the comparative tolerance to simazine of a range of species (e.g., apple and rose rootstocks are less affected than strawberry, or raspberry, but anemones more so). Because the roots of the crop plants in these trials were surrounded by treated soil, the moderate resistance of strawberry and raspberry and the greater resistance of apple and rose rootstocks cannot be entirely the result of depth protection, but must reflect varying degrees of innate tolerance to simazine. Under conditions where roots penetrate deeply and the chemical remains near the surface, depth protection contributes an additional safety factor. Caseley (1960), working with fruit plants growing in sand culture, has also demonstrated the high resistance of apple and the lower resistance of raspberry to simazine applied to the surface of the sand and washed down by nutrient solution.

Where comparisons have been made between simazine treatments applied to the surface and mixed in to the full depth of soil, it is of interest to note that the doses required to cause injury have not generally been very much greater with the surface treatment. This suggests that there is considerable downward movement of simazine through the soil in pots under glasshouse conditions. A less likely alternative explanation would be that most of the uptake of herbicide takes place from the upper layers of the soil.

Although the results of the present trials agree in general with those of field work, it is evident that careful standardisation of plant material and technique is required to obtain valid results where relatively small varietal and seasonal differences in susceptibility are concerned. The size of plants is a very important factor, as, for example, was shown in the trial with simazine on raspberry, in which small plants were very much more sensitive than larger ones. This also has been observed in the field. With larger plants, although the transpiring surface and thus the uptake of chemical is greater than with small ones, the rate of simazine inactivation is also presumably greater and the balance between uptake and inactivation favours inactivation. Transplanting and growing conditions can also be expected to be important.

Preliminary indications that Cambridge Favourite strawberry are somewhat more resistant to simazine than Huxley have been obtained in these experiments, but confirmation is required from further pot and field trials. In any case the difference between the two does not appear to be as great as that suggested by Caseley's results, where a dose causing moderate injury to Huxley and other varieties was without effect on Favourite. The results suggesting that Rosa laxa is appreciably more resistant to prometryne than R. canina also need confirmation. The difference observed between these two species might possibly be connected with the difference in degree of defoliation that occurred. With R. laxa, which was rapidly and completely defoliated, uptake of chemical may have been less than with R. canina because of the absence of leaves. R. canina was only partly defoliated and presumably continued to take up the herbicide.

The results from the present trials comparing the effects of simazine on strawberries at different times of year are inconclusive and a new series of trials has been started to obtain more information on this point. The results from the trial with activated charcoal show that some protection against the action of simazine is provided even in pots. The degree of protection in pots, however, would not be expected to be of the same order as in the field, where roots are able to grow downwards and away from the layer of soil containing herbicide.

Acknowledgments

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TRIALS OF HERBICIDES ON NARCISSUS AND TULIP

Elizabeth D. Turquand

Kirton Experimental Husbandry Farm, Boston, Lincs.

Summary. In a series of experiments lasting three years, various contact herbicides were used for pre-emergence weed control on narcissus and tulip, and their action was assessed for deleterious effects on the crop plants. Diquat, paraquat, dinoseb, dimexan and pentachlorphenol, applied at the stated rates per acre to beds of narcissus and tulip pre-emergence in early winter, were safe and effective, and had no serious residual effects when bulbs from treated plots were forced.

INTRODUCTION

When sodium arsenite became unobtainable as a contact herbicide for weed control on fields of tulip and narcissus, bulb growers found it difficult to replace. While substitutes were available for contact weed control, they did not have an equally efficient residual effect on weed germination.

Lees and Wallis (1962) applied a large number of herbicides at three rates to narcissus at three stages of growth at Rosewarne Experimental Horticultural Station to test the effect of some of the sprays which might be used, while Beech et al. (1962) reported on trials using diquat and paraquat for pre-emergence weed control on narcissus and tulip. Experiments on tulip and narcissus began at Kirton in 1960, applying chiefly those contact herbicides used locally for such purposes as potato haulm destruction. These herbicides were applied at one rate only, pre-emergence in early winter, to beds of tulip and narcissus planted 2 to 3 months previously. During the first year it was found that weed growth in the following spring complicated the picture, because the herbicides lacked residual effect on weed germination. In subsequent years chlorpropham was added to all the herbicides to prevent excessive weed germination, but in commercial practice growers would apply a residual herbicide separately later in the season. The experiments were concluded by forcing bulbs of uniform size from all treatments, since it had been found that forcing conditions sometimes showed residual differences which might pass unnoticed in the field.

METHODS AND MATERIALS

250 narcissus or tulip bulbs of uniform weight and size were planted in beds 10 ft. long by $3\frac{3}{4}$ ft. wide, each containing 5 rows 9 inches apart. Treatments were replicated in randomised blocks. The bulbs used were grown on the farm at Kirton and the narcissus were hot water treated at 110°F for 3 hours before planting.

An Oxford Precision Sprayer applying 100 gal/ac. of water was used for all the herbicides. Where chlorpropham was added it was mixed with the contact herbicide immediately before application. Weed cover at the time of application was always light owing to the relatively short interval between planting and the pre-emergence application.

Plots were checked for visual damage, and weed cover was assessed by scoring at intervals during the growing season. After lifting plot weights and numbers of bulbs in the various grades were recorded. Bulbs from the replications were then bulked and bulbs for forcing selected from the same forcing grade in every treatment. At least 4 boxes from each treatment, each containing 35 narcissus or 40 tulip bulbs, were placed in randomised blocks on the standing ground and glasshouse bench. The forced flowers were cropped at a uniform stage of growth, and graded by eye into firsts and seconds according to size, colour, and general appearance. If a flower was graded as a second the reason for down grading was given. Mean flowering date was also noted.

RESULTS

Tables 1, 2 and 3 show the effects of various contact herbicides, with and without chlorpropham, on the weight of bulbs lifted and the type of flower produced on forcing in the subsequent year with narcissus Carlton in 1960/61 and 1961/62, and Fortune in 1962/63.

TABLE 1

Effects of herbicides on narcissus Carlton planted 14 October 1960, lifted July 1961 and forced in March 1962.

Herbicide lb/ac of a.i. applied on 2 December 1960	Mean yield lb/ plot	% Weed cover 9.6.61	Flowers forced March 1962 Marketable blooms/box	Grade 1 % blooms
Diquat 2	49.2	75	66.5	78.5
Dimexan 8	49.3	85	67.0	77.5
PCP 6	50.0	65	65.5	77.0
Diquat 2 + chlorpropham 2	49.7	45	66.2	74.0
Dinoseb (amm*) 3 + chlorpropham 2	50.6	25	66.8	75.8
PCP 6 + chlorpropham 2	50.4	35	65.5	71.2
Cultivated	50.7	25	64.5	75.2
Control	49.4	90	64.2	75.8
Mean	49.9		65.8	75.6
s.e. of diff between means (21 d.f.)	±0.71		±2.40	±5.22
Least significant difference (P = 5%)	1.5		5.00	10.9
s.e. as % of mean	2.0		5.2	9.8

*An ammonium formulation of dinoseb was used throughout this series of experiments because it had been used in previous experiments on the farm.

Heavy rain flooded all plots from 3 to 5 December 1960 immediately after the herbicide applications but neither field nor forcing trial showed significant differences between treatments, except in flowering date during forcing, when the maximum difference was only 1.3 days between the earliest and latest chemical treatment. This difference did not occur in subsequent years.

TABLE 2

Effects of herbicides on narcissus Carlton planted 18 September 1961 lifted July 1962 and forced in March 1963.

Herbicide lb/ac of a.i. applied on 16 November 1961	Mean yield lb/ plot	% weed cover 19.6.62	Flowers forced March 1963 Marketable blooms/box	Grade 1 blooms/ box	Small blooms /box
Diquat 2 + chlorpropham 2	51.5	16	66.8	51.4	10.6
Paraquat 2 + chlorpropham 2	51.3	15	66.9	51.5	9.6
Dimexan 8 + chlorpropham 3*	50.7	9	68.0	50.1	11.0
Dinoseb (amm) 3 + chlorpropham 2	51.0	13	65.9	50.2	9.6
PCP 6 + chlorpropham 2	51.9	11	67.2	53.0	8.4
Propanil 1.66 + chlorpropham 2	52.2	19	68.6	53.8	8.1
Cultivated	51.1	5	67.4	54.9	8.1
Control	44.9	100	67.6	48.6	13.9
Mean	50.6		67.3	51.7	9.9
s.e. of diff betw. means (21 d.f.)	±1.27				
s.e. " " " " (49 d.f.)			±1.23	±2.49	±1.76
Least significant difference (P=5%)	2.6		2.5	5.0	3.5

*Chlorpropham was applied at 3 lb/ac in error for 2 lb/ac.

TABLE 3

Effects of herbicides on narcissus Fortune planted 22 October 1962, lifted July 1963, forced February 1964.

Herbicide lb/ac of a.i. applied on 12 and 14 December 1962	Mean yield lb/ plot	% weed cover 26.6.63	Flowers forced February 1964 Marketable blooms/box	Grade 1 % blooms
Diquat 2 + chlorpropham 2	44.6	45	68.8	83
Paraquat 2.76 + chlorpropham 2	44.5	80	66.8	80
Dimexan 8 + chlorpropham 2	44.8	65	67.2	84
Dinoseb (amm) 3 + chlorpropham 2	44.4	30	68.8	83
Dinoseb (in oil) 3 + chlorpropham 2	45.2	35	68.2	83
Propanil 1.66 + chlorpropham 2	43.5	70	66.0	81
OMU + BiPC 1.14 + chlorpropham 2	45.4	60	68.0	81
Hand weeded	45.0	100	69.8	82
Cultivated	44.3	100	67.8	79
Control	42.6	100	69.5	87
Mean	44.4		68.1	82
s.e. of diff. between means (27 d.f.)	±0.85		±1.80	±3.2
Least significant difference (P=5%)	1.8		3.7	7

These three experiments showed no herbicide damage in the field and no significant difference between the yields of the chemical treatments. There was a significant reduction in yield on the weedy control plot compared with the plots where weed was controlled either by cultivation or herbicide application in 1961/2 and 1962/3. (Tables 2 and 3)

During forcing the only difference noted between treatments was a tendency for the control plot to produce fewer first grade flowers, together with a significant increase in small flowers compared with the cultivated treatments in March 1963 (Table 2).

Contact herbicides applied pre-emergence to beds of tulip

1960/1. Similar treatments to those applied to narcissus in December 1960 (Table 1) were applied to tulip Golden Harvest on 16 December 1960. Heavy rain followed immediately but no damage was noted which could be attributed to the herbicides, either in the field or during forcing, although some plots suffered from waterlogging in the field.

Tables 4 and 5 show the effects of treatments similar to those applied to narcissus, when applied to tulip Rose Copland 1961/2 and tulip Golden Harvest 1962/3.

TABLE 4

Tulip Rose Copland, planted 16 October 1961, lifted July 1962, forced March 1963.

Herbicide lb/ac of a.i. applied on 14 December 1961	Mean yield lb. adjusted to 229 stands	Flowers forced March 1963 No. of Grade 1 blooms/box	Grade 2 % blooms
Diquat 2 + chlorpropham 2	17.7	18.5	45.0
Paraquat 2 + chlorpropham 2	18.1	22.2	30.2
Dimexan 8 + chlorpropham 3	18.8	21.5	38.8
Dinoseb 3 + chlorpropham 2	17.6	23.5	31.0
PCP 6 + chlorpropham 2	18	21.2	38.2
Propanil 1.66 + chlorpropham 2	18.3	25.8	28.5
Cultivated	19.2	20.8	38.8
Control	18.1	23.5	31.5
Mean	18.2	22.1	35.2
s.e. of diff between means (21 d.f.)	±0.67	±2.11	±5.27
Least significant difference (P=5%)	1.4	4.4	11
s.e. as % of mean	5.2	13.5	21.2

The growing conditions in 1960/1 produced soft bulbs liable to rot in the ground in the 1961/2 season. Slight Grey Bulb Rot (Sclerotium tuliparum) was also present and although 250 bulbs were planted per plot the mean stands per treatment varied between 217 and 233, so that it was necessary to adjust yields to 229 stands per plot by proportion. No damage due to herbicides was noted in the field, but in forcing the diquat/chlorpropham treatment gave fewer grade 1 flowers per box than the control plot, with a significantly higher percentage of grade 2 blooms.

TABLE 5

Tulip Golden Harvest, planted 22 October 1962, lifted July 1963, forced March 1964.

Herbicide lb/ac of a.i. applied on 12 and 14 December 1962	Mean yield lb/plot	Flowers forced March 1964 Marketable blooms/box	Grade 1 % blooms
Diquat 2 + chlorpropham 2	19.0	35.0	45
Paraquat 2.76 + chlorpropham 2	19.0	36.8	52
Dimexan 8 + chlorpropham 2	18.5	33.2	44
Dinoseb (amm) 3 + chlorpropham 2	19.2	34.5	57
Dinoseb (oil) 3 + chlorpropham 2	20.2	33.0	58
Propanil 1.66 + chlorpropham 2	19.2	35.8	57
OMU + BiPC 1.14 + chlorpropham 2	20.0	35.5	46
Handweeded	19.2	34.8	49
Cultivated	20.7	35.2	50
Control	20.2	34.5	44
Mean	19.5	34.8	50
s.e. of diff between means (27 d.f.)	±0.66	±2.56	±8.4
Least significant difference (P=5%)	1.4	5.3	17

No significant differences were noted, either in the field or during forcing.

DISCUSSION

This series of experiments was designed to check the effect on bulbs rather than the efficiency of various contact herbicides available to growers for pre-emergence application to narcissus and tulip. Reasons for the choice of herbicides included were varied. PCP and dinoseb had previously been used in experiments on bulbs at Kirton Experimental Husbandry Farm to control seedling weeds and the rate of application was decided by these experiments. By 1962/3 it was considered safe to use PCP on the stock bulbs on the farm and it was omitted from this series of experiments. Dinoseb usually gave the best weed control at the end of the season each year, and dinoseb in oil formulation was included for comparison later when the product was introduced for potato haulm destruction. Propanil and OMU + BiPC were used because no damage or yield reduction were noted in experiments when they were applied post emergence, as late as March, to both tulip and narcissus, and this was considered a valuable asset in a contact herbicide. Dimexan was introduced from the Netherlands for control of seedling weeds in tulip beds. Diquat was in use as a contact spray when this series of experiments began, but the rate per acre was not reduced to the makers' final recommendations for contact weed control. The rate of paraquat was raised, however, to bring it in line with the product available to growers because of its value for grass control.

All these contact herbicides gave a good kill of seedling weeds which were the only type present at the time of application, and although weed cover as indicated by the June figures in Tables 1 to 3 showed differences, these developed too late to have any effect on yield except in the case of the narcissus control plots. The main weeds present at the end of the season on the control plots were Stellaria media, Veronica spp, Matricaria spp, Papaver rhoeas, Polygonum spp, Capsella bursa-pastoris and Senecio vulgaris. The herbicide sprayed plots all showed the same range of weeds at the end of the season, any differences being in the date by which the weeds germinated.

No visual damage was noted in the field in any of the growing seasons, in spite of widely varying weather conditions which included flooding after application in 1960, and the only serious reduction in yield was caused by weed growth on the narcissus control plots in 1961/2 and 1962/3 (Tables 2 and 3).

During the forcing of residual bulbs from these experiments the only sign of any possible ill effect from a chemical treatment was on tulip Rose Copland, treated with diquat in December 1961 and forced in March 1963 (Table 4), when a slight reduction in the number of first grade flowers compared with control, and significant increase in the percentage of second grade flowers was noted. This did not occur in other years when tulip Golden Harvest was used however, and since Rose Copland was not available for subsequent experiments, it was not possible to investigate whether this was a seasonal or varietal effect associated with Rose Copland, or the appearance of an effect arising merely from chance fluctuations. Weed growth on the narcissus control plots probably accounted for the reduced number of first grade flowers, and the significant increase in small flowers from these plots compared with other treatments, during the forcing of narcissus Carlton in March 1963 (Table 2).

The soil on which the bulbs were grown at Kirton Experimental Husbandry Farm was a very fine sandy loam which tended to pack fairly close, and there was little danger of the herbicides coming in direct contact with the bulbs since at the time of application the narcissus were well rooted with shoots about an inch below the surface, and the tulips were rooting but had only just started to shoot. The use of these contact herbicides appears to be safe when they are applied pre-emergence to beds of narcissus and tulip, and the choice, which would depend on the type of weed growth to be controlled, may be left with the grower.

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HERBICIDE TRIALS ON DAHLIAS

D.V. Clay and G.W. Ivens
A.R.C. Weed Research Organisation, Begbroke Hill, Oxford.

Summary In a series of field and pot trials, simazine was the most effective of a number of herbicides tested on dahlia. A dose of 1 lb/ac caused slight leaf injury, but did not affect flower production; 2 lb/ac caused more serious injury. Varieties differ in susceptibility to simazine, Dr. Grainger and Edinburgh being the most resistant of those tested, Jescot Hilda and Marion Lister among the most susceptible. Dahlias planted as divided tubers appeared to be somewhat less liable to damage than rooted cuttings. Under glasshouse conditions high doses of simazine applied on the leaves caused injury, but only to leaves contacted by the spray. The doses used in the field are thought unlikely to have an appreciable effect through the leaves.

INTRODUCTION

In addition to being one of the most popular flowers for garden decoration, certain varieties of dahlia are grown widely as a cut-flower crop, frequently on soils of high fertility with large weed populations. The only standard herbicide treatment is a directed spray of a cresylic acid formulation (Woodford & Evans 1963), which will control many dicotyledonous weeds as seedlings, but has no residual action. Overall sprays of 2,4-DES have also been used successfully. They have not come into widespread use, however, because of limitations in the range of species controlled and the duration of control. Chlorpropham (with or without small amounts of fenuron or diuron) has been tested on a small scale (Luddington 1962) and appears relatively safe, but is not at its most effective in early summer when dahlias are planted, and resistant weed species are often important. Diquat applied in the same manner as cresylic acid formulations has been shown to cause considerable injury (Luddington 1961, Fairfield 1963a).

Simazine has given variable results. At Luddington (1961) 1 lb/ac overall caused injury to two varieties planted as rooted cuttings, but not to a third. In the next year (Luddington 1962) 0.5 lb/ac caused no injury to two varieties planted as divided tubers and twelve varieties were uninjured by 1 lb/ac in an observation trial. At Fairfield a dose of 1 lb/ac was used as a directed spray on rooted cuttings for three years without causing injury (Fairfield 1963a).

The present series of trials was commenced in 1962 with the main aim of finding out how far factors such as variety, type of planting material and method of herbicide application were responsible for the variable results given by simazine. Small-scale screening trials were also conducted with several other herbicides.

METHODS AND MATERIALS

The series of trials with simazine consisted of 3 field trials conducted on a sandy loam soil at Begbroke. In experiment 'A' an overall spray of simazine at 1 and 2 lb/ac was tested on 5 varieties planted as rooted cuttings; in 'B' the same doses were applied to two types of planting material, rooted cuttings and divided tubers, in 'C' comparisons were made between overall and directed sprays, and between wettable powder and granule formulations. Details of replication, planting and spraying dates and weather conditions relating to the field trials are given in Table 1. The normal 50% wettable powder formulation of simazine was used and application was by Oxford Precision Sprayer at a volume rate of 50 gal/ac. The granules contained 4% simazine formulated on calcium carbonate and were applied with a small hand sprinkler. Four plants of each variety and type of planting material were used in each plot.

Cuttings were raised in the normal way, rooted in a sand/peat mixture and potted into potting compost or soil. Divided tuber planting material was obtained from tubers which had already been used for the production of cuttings.

In addition to the field trials an experiment with 3 varieties growing in pots was carried out in the glasshouse to investigate the possible action of simazine through the foliage. Doses of 2 and 10 lb/ac were employed, either without additional wetter or with the addition to the spray solution of the wetting agents Triton X 100, X 114 or B 1956 to give a concentration of 0.1%. The sprays were applied at a rate of 29 gal/ac to the foliage of plants 14 - 16 in. high growing in $6\frac{1}{2}$ in. plastic pots. To prevent access of chemical to the roots, the soil surface was covered with polythene at the time of spraying. Care was taken in subsequent watering to avoid any wetting of the leaves, but as an additional safeguard to prevent simazine getting into the soil, a layer of steam-activated charcoal was placed on the soil surface.

Table 1.
Details of three field trials with simazine on dahlias.

Experiment		'A' (1962)	'B' (1963)	'C' (1964)
Varieties grown		Chorus Girl Doris Duke Jescot Duo Jescot Hilda Marion Lister	Chorus Girl Doris Duke Dr. Grainger Jescot Hilda Marion Lister	Dr. Grainger Marion Lister Newby
Planting date		14/6	30/5	9/6
Spraying date		25/6	11/6	23/6
Replicates		3	3	3
Rainfall (in.)	Week before spraying	0.07	0.22	0.42
	Day before	0	0	0
	Day after	0	0	0
	Week after	0.09	0.49	0
	Month after	0.79	2.21	0.58

RESULTS

Experiments with simazine.

In experiment 'A', the 1 lb/ac dose of simazine caused no obvious damage to the crop. With 2 lb/ac, however, severe necrosis of the foliage developed on Chorus Girl and there was moderate injury with Marion Lister. A month after spraying this effect was at its worst, but growth thereafter was more or less normal, though the affected plants remained reduced in size. With the other varieties, Jescot Duo, Jescot Hilda and Doris Duke, the higher dose caused little obvious damage. Some plants of Dr. Grainger present in two of the replicates were also unaffected. The effect on flower production over the period 10th August to 26th October is shown in Table 2 and it is clear that the two varieties showing leaf damage at the higher dose also produced significantly fewer flowers.

Table 2.
The effect of simazine on flower production of 5 varieties of dahlia. (Experiment 'A')

Variety	Chorus Girl	Doris Duke	Jescot Duo	Jescot Hilda	Marion Lister	Mean
	Mean no. flowers picked per plant over season					
Treatment						
Control	57	53	36	62	46	51
Simazine 1 lb/ac	53	57	41	69	43	53
Simazine 2 lb/ac	42	51	39	67	28	45
Mean	50	54	38	66	39	

Sig. diff. (P = 0.05) treatments 10, variety x treatment interaction 11.

In the 1963 trial (Experiment 'B'), which took place during a wetter summer than 1962, there was again little injury with a dose of 1 lb/ac (slight necrosis on a few leaves with Jescot Hilda) and appreciable injury with 2 lb/ac. The higher dose caused slight to moderate necrosis with most varieties and this was worst with Jescot Hilda, least with Doris Duke.

Table 3.
Effects of simazine on flower production of 5 varieties of dahlia planted as divided tubers (T) or rooted cuttings (C) (Experiment 'B')

Treatment		Chorus Girl		Doris Duke		Dr. Grainger		Jescot Hilda		Marion Lister		Mean
		Mean no. flowers picked per plant over season										
Control	T	53	63	42	51	37	50	41	54	29	40	40
Control	C	74		59		64		68		51		63
Simazine 1 lb/ac	T	58	61	43	54	42	58	41	51	31	40	43
	C	64		65		75		61		49		63
Simazine 2 lb/ac	T	44	54	35	44	40	46	32	32	15	21	33
	C	63		54		53		31		28		46
Sig. diff. treatment means (P=0.05)		NS		7.2		NS		16		15		

Treatment x planting material interaction NS but approaching significance with Jescot Hilda.

As shown in Table 3, the total production of flowers was reduced with Jescot Hilda and Marion Lister, but the effect on the other three varieties was slight. With Jescot Hilda there was a clear difference in the effects on plants planted as rooted cuttings and divided tubers, the cuttings being the more severely affected.

Table 4.
The effects of simazine on numbers of flowers produced by a resistant and a susceptible dahlia variety over different parts of the picking season (Exp.'B')

	Mean no. flowers picked per plant (average from rooted cuttings and divided tubers)					
	Dr. Grainger			Marion Lister		
Days from 1st pick	0-25	26-50	51-75	0-25	26-50	51-57
Treatments						
Control	14	24	12	8	20	12
Simazine 1 lb/ac	13	28	15	8	20	11
Simazine 2 lb/ac	10	22	14	3	11	7

In Table 4 the effects of the higher dose of simazine on the numbers of flowers produced during different parts of the picking season are shown for Dr. Grainger, relatively resistant, and Marion Lister, a relatively susceptible variety. It appears that even with the resistant variety there was some reduction in flowering initially, but later on the numbers of flowers produced returned to normal. With the susceptible variety, on the other hand, not only was the initial reduction greater, but very little recovery occurred.

In 1964 (Experiment 'C') a comparison was made between overall application and directed application achieved by covering the plants with 6-in. pots. The effects of the normal wettable powder and a 4% granule formulation on flowering are shown in Table 5 and it is clear that, under the very dry conditions prevailing in this season, even the 2 lb/ac dose had no effect on the varieties Dr. Grainger and Newby. On Marion Lister the wettable powder caused a reduction in flowering at the higher dose, but the granule formulation did not, and the effect was very much the same whether the treatment was applied as an overall or a directed spray.

Table 5.
Effects of wettable powder and 4% granular formulations of simazine applied as overall or directed treatments to 3 varieties of dahlia. (Experiment 'C')

	Mean flowers picked/plant over season					
	Dr. Grainger		Marion Lister		Newby	
Treatment	W.P.	granule	W.P.	granule	W.P.	granule
Control	11.8		9.6		9.6	
Simazine 1 lb/ac						
Overall	12.0	12.2	9.0	8.7	11.2	11.6
Directed	14.9	11.3	9.2	10.8	9.2	11.2
Simazine 2 lb/ac						
Overall	11.7	10.7	6.8	8.2	9.0	10.2
Directed	12.9	12.3	6.9	9.8	11.3	10.3

Observations of the degree of injury caused by foliage application of simazine with or without additional wetting agent to plants in pots are shown in Table 6. In this trial necrosis developed at the margins of leaves that were fully expanded when sprayed. The necrosis was largely restricted to the marginal parts of the leaves, but some leaves died completely. The damage reached its maximum extent about a month after spraying and there were no signs of chemical being translocated to other parts of the plant from the leaves originally sprayed. With the 2 lb/ac dose, only Jescot Hilda showed injury, but with the higher dose of 10 lb/ac all varieties were injured to varying extents. There was no indication that addition of any of the three wetting agents increased penetration of simazine.

Table 6.

Effects of simazine, with and without additional wetting agents at 0.1%, application confined to foliage of 3 dahlia varieties (injury scored on scale 0 = normal - 5 = all foliage dead)

Treatment	Doris Duke		Jescot Hilda		Newby	
	No. of leaves injured	score for injury (0-5)	No. of leaves injured	score for injury (0-5)	No. of leaves injured	score for injury (0-5)
Control	0	0	0	0	0	0
Simazine 2 lb/ac						
No additive	0	0	2	1.5	0	0
+ Triton X 100	0	0	1	1.5	0	0
+ Triton X 114	0	0	5	2	0	0
+ Triton B 1956	0	0	2	1	0	0
Simazine 10 lb/ac						
No additive	3	1.5	7	2.5	2	1
+ Triton X 100	6	2	8	2.5	5	2.5
+ Triton X 114	5	2	5	2	4	2
+ Triton B 1956	3	1	9	3	4	1.5

Screening trials with other chemicals.

In addition to the replicated trials with simazine, observation trials were carried out with other herbicides and with simazine on a wider range of varieties. In 1963 for example, Newby, Glorie van Heemstede and Helly Boudewijn were found to be among the varieties least tolerant to simazine (similar in sensitivity to Marion Lister), Golden Leader was moderately susceptible and Edinburgh one of the most tolerant.

Of the other chemicals applied as overall sprays, chloroxuron was tested on a range of species at 5 lb/ac and resulted in a degree of injury similar to that caused by simazine at 2 lb/ac, thus showing little selectivity in dahlias. Chlorpropham alone caused no obvious injury at 4 lb/ac, but when mixed with diuron in 1962 (chlorporpham 2 lb + diuron 0.4 lb/ac as 'Residuren') there was very severe damage. In the next year a different formulation was tested (chlorpropham 2 lb + diuron 0.8 lb/ac as 'New Residuren') and damage was only slight. Diuron alone at 2 lb/ac reduced flower production by 50%. In 1964, dimethyl 2,3,5,6-tetrachloroterephthalate (Dacthal) 8 lb/ac, trifluralin 5 lb/ac and diphenamid 5 lb/ac were also tested and caused no apparent injury, but the conditions of this experiment were so dry that penetration of the chemical into the soil, and uptake into the plant, is likely to have been minimal. Under the same conditions simazine at 2 lb/ac had little or no effect on several varieties.

DISCUSSION

Of the herbicides tested on dahlias, simazine at present appears to offer the best combination of effectiveness and safety. Chlorpropham is safer but less effective, especially under summer conditions, and the addition of diuron to improve herbicidal properties leads to increased danger of damage. The safety margin with simazine is not high, as is shown by the widespread occurrence of damage with a dose of 2 lb/ac, but 1 lb/ac is usually sufficient to control annual weeds for most of the growing season and has never caused more than slight injury in the present trials.

The results show that dahlias suffer more injury from simazine in a wet than in a dry season and it is possible that under wetter conditions than those experienced in the present trials, even 1 lb/ac might be sufficient to injure the more sensitive varieties. The risk of injury is greatest on light soils deficient in organic matter and on such soils it would appear advisable not to exceed doses of the order of 0.5 - 0.75 lb/ac.

It is clear that varieties differ considerably in resistance to simazine. The most resistant of those tested appeared to be Dr. Grainger and Edinburgh, the most susceptible Jescot Hilda, Marion Lister, Newby, Glorie van Heemstede and Helly Boudewijn, with Chorus Girl, Doris Duke, Golden Leader and Jescot Duo intermediate. Relative susceptibility, however, has not always been the same from year to year and Newby, which in 1963 appeared outstandingly sensitive, was less affected than Marion Lister in 1964. Results from Experimental Horticulture Stations (Luddington 1961, Fairfield 1963a) confirm the resistance of the two most resistant varieties. With other varieties there is less agreement and it is likely that apparent resistance is influenced by soil and climatic conditions.

Dahlias planted as divided tubers would be expected to have fewer roots near the surface than rooted cuttings when a herbicide treatment is applied a week or two after planting. The finding in the 1963 trial that tubers of one variety were less liable to injury than cuttings is therefore not surprising. Tubers generally produced fewer blooms than cuttings in this trial, but when planted out in early May instead of late May a reduction in numbers would not normally occur.

The data on directed spraying obtained in the present trials are not conclusive, as the comparison between directed and overall application was made in a very dry season when little injury occurred with any treatment. The information obtained, however, suggested that there was little difference between overall spraying and spraying to within 3 in. of the base of the plant. The pot trial also showed that, although simazine at 10 lb/ac applied to the leaves caused appreciable injury, 2 lb/ac had only a slight effect on a sensitive variety. Leaf uptake would be expected to be greater on the soft growth of glasshouse-grown plants than with plants hardened off in the field, so that injury to plants in the field as a result of uptake through the leaves seems very unlikely with doses of the order of 1 lb/ac.

Results of a trial at Fairfield (1963b) showed that directed application (spraying close to the ground) of simazine at 1 lb/ac caused little or no injury to 6 dahlia varieties which were badly injured or killed by an overall spray. The conclusion that the increased damage is due to a contact effect on the leaves is at variance with the evidence from the present trials. In the pot trial, not only was there little or no damage with a dose of 2 lb/ac, but even with 10 lb/ac only the leaves covered by the spray were affected. This contrasts with the type of injury normally noted in field experiments, where successively younger leaves become necrotic and the whole plant may die. It seems likely, therefore, that the reduced injury noted with directed application may be due, less to the absence of a contact effect, than to smaller proportions of the root system being exposed to the herbicide.

Acknowledgements

Thanks are due to the Lee Valley and Fairfield Experimental Horticulture Stations who supplied the original stocks of dahlia plants used in these trials.

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EXPERIMENTS ON WEED CONTROL IN SOWN FLOWER CROPS

G. W. Ivens
A.R.C. Weed Research Organisation, Begbroke Hill, Oxford.

Summary A series of 5 experiments is described in which various residual herbicides were applied as pre- or post-emergence treatments to 14 hardy annual, half-hardy annual and biennial flower crops. Of the chemicals tested, chlorpropham, propham and chloramben were selective in the greatest number of species. Fenuron, diuron, chloroxuron, simazine and prometryne had little selective action and neburon and 2,4-DES were intermediate. Members of the Compositae and wallflower (*Cheiranthus cheiri*) were relatively resistant to chlorpropham and propham at the doses used. Sweet pea (*Lathyrus odoratus*) and larkspur (*Delphinium consolida*) were resistant to most chemicals, including small doses of simazine; gypsophila (*G. elegans*) and sweet william (*Dianthus barbatus*) were susceptible to all. It is concluded that chlorpropham and chloramben are the two most promising herbicides for a range of sown flower crops, the utility of chlorpropham being restricted to autumn and early spring.

INTRODUCTION

Although not grown on large acreages, a number of annual and biennial flowers are of local importance as cut-flower crops. Several others, especially wallflower, are used extensively as bedding plants. Certain contact pre-emergence sprays are the only treatments currently recommended for weed control in these crops (Woodford and Evans 1963), but are of limited value, because many of the species concerned are rapid germinators and thus emerge together with the weeds. Weeds germinating later can also be a problem, often only capable of solution by means of expensive hand-hoeing so that there is a need, either for selective post-emergence treatments or for soil-applied herbicides with a residual action. Very little information on the effects of herbicides on these crops in Britain is available, but various residual chemicals have shown promise on the continent (Detroux 1959) and in Canada (Warren 1960). A series of trials on several of the more commonly grown flower species was accordingly started in 1960.

MATERIALS AND METHODS

Five experiments have been conducted, all on alluvial, light loam at Begbroke. These included pre-emergence trials in the autumn of 1960 and the spring or early summer of 1961, 1962 and 1963, and a post-emergence trial in the early summer of 1961. Details of sowing and spraying dates and rainfall are given in table 1. In the one post-emergence trial (experiment C) the various species were 3-6 in. high when sprayed. Experiments A, B and C were finite dose trials with 3 or 4 replicates, in which 9 ft lengths of row of the various species were sprayed with an Oxford Precision sprayer at 50 gal/ac. Experiments D and E were sprayed with a logarithmic sprayer, single rows of the various species being included in each of 2 replicates. In D, the small-scale, electrically-driven machine described by Fryer (1956) was used at a volume rate of 76 gal/ac.

Table 1

Details of experiments on sown flower crops carried out in 1960-1963

	A 1960 pre-em	B 1961 pre-em	C 1961 post-em	D 1962 HA pre-em	D 1962 B + HHA pre-em	E 1963 pre-em
Sowing date	20/9	1/5	1/5	19/4	29/5	18/5
Spraying date	23/9	5/5	21/6	24/4	5/6	27/5
Replicates	4	3	3	2	2	2
Soil surface	moist	dry	v. dry	dry	v. dry	dry
Rainfall (in.)						
Week before spraying	1.26	0.58	0.03	0.64	0.08	0.56
Day before	0.69	0.22	0	0.02	0	0
Day after	0	0	0.02	0	0	0
Week after	0	0.03	0.09	0	0.02	0.28
Month after	2.94	0.13	1.39	0.64	0.18	1.23
Assessment dates	20/11	8/6 30/6 11/8	30/6 11/8	7/6 13/9	13/9	30/7

HA = hardy annuals B = biennial HHA = half-hardy annual

In E, a prototype of the Fisons Mini-Log sprayer was tested (at 39 gal/ac), but owing to mechanical troubles it was only possible to apply 2 of the 6 chemicals planned.

The crops were sown at normal depths (sweet peas and zinnia by hand, the rest with a Planet Junior drill). The varieties used were as follows: aster (Callistephus chinensis) var. Ostrich Plume mixed; calendula (C. officinalis) var. Suttons Orange King; chrysanthemum (C. carinatum) var. Tricolor mixed; cornflower (Centaurea cyanus) var. Suttons Double Blue; gypsophila (G. elegans) var. White Covent Garden; larkspur (Delphinium consolida) var. Stock-flowered, Double-branching, dark-blue; scabious (Scabiosa atropurpurea) var. Double Large-flowered, cherry red; stock (Matthiola incana) var. Large-flowering 10 week, mixed; sweet pea (Lathyrus odoratus) var. Crimson Excelsior; sweet sulton (Centaurea moschata) var. Choice mixed; sweet william (Dianthus barbatus) var. Auricula-eyed, mixed; tagetes (T. signata) var. Golden ring; wallflower (Cheiranthus cheiri) var. Choice mixed; zinnia (Z. elegans) var. Giant Double Mammoth, mixed.

Most of the herbicides were used as normal commercial formulations, chlorpropham as 40% emulsifiable (Craven's Isoclor); propham as 20% emulsifiable (Bugge's); 2,4-DES 93% (Bugge's Zide No. 4); fenuron 25% wettable powder (Bugge's Zide No. 3); diuron 80% wettable powder; neburon 50% wettable powder; chloroxuron 50% wettable powder; chloramben 24% amine salt; simazine and prometryne 50% wettable powders.

Assessments were made at various intervals as shown in table 1; counts and observations of damage in trials A, B and C, measurements of maximum doses at which plants survived and at which they grew normally in the logarithmic trials.

RESULTS

Effects on crops

The resistance or susceptibility of the various species to the range of chemicals tested in the 5 trials is summarised in table 2, where, for the sake of clarity, the results of the logarithmic trials are expressed in terms of the same doses as those employed in the finite dose trials. The symbol R has been used where there was no damage, or where the effect was slight and temporary; where (R) appears in brackets it signifies that, in one or two replicates, somewhat greater damage was observed, though it was still considered to be temporary. S denotes appreciable reduction in growth or stand.

Weather and soil conditions differed considerably between the various trials and affect the significance of the results given in the table. Experiment A, for example, was started at the beginning of a very wet, cold autumn and winter which favoured damage with the less soluble compounds, such as neburon, diuron and chlorpropham, and also resulted in few plants surviving until spring, so that no valid assessments of damage could be made later than November. The pre-emergence treatments on biennial and half-hardy annual species in 1962 (experiment D), on the other hand, were applied under very dry conditions and the weather remained dry for a considerable period. This favoured resistance to the more insoluble compounds, but at the same time resulted in poor establishment. The dry conditions following herbicide application in experiment C were less important, as this was a post-emergence trial.

It is evident from the results that some of the chemicals had little selective action in the range of flower crops tested. In particular diuron, fenuron, chloroxuron, simazine and prometryne killed the majority of the crops at doses required to kill weeds, only sweet pea and larkspur showing apparent resistance. Chlorpropham, propham and chloramben, however, were tolerated by many species, 2,4-DES and neburon by somewhat fewer. Neburon tended to cause more damage as a post-emergence than as a pre-emergence treatment. **Mixtures** of chlorpropham at 1 or 2 lb/ac with fenuron or diuron at 0.25 or 0.5 lb/ac were also tested in experiment A and had the effects that would be expected from the behaviour of the two individual components. All caused appreciably more damage than chlorpropham alone.

The flower species also varied widely in susceptibility, with sweet pea being outstandingly resistant, presumably because it was sown at a much greater depth than the others. Larkspur, wallflower, aster, cornflower and calendula showed resistance to about half the chemicals while, at the other end of the scale, gypsophila, sweet-william and stock were susceptible to all treatments.

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Table 2

Summary of the results of 5 experiments with a range of residual herbicides, each at 2 doses, on various hardy annual (HA), half-hardy annual (HHA) and biennial flower crops (R = resistant, (R) = borderline, S = susceptible)

Crop	Experiment	chlorpropham 1	chlorpropham 2	propham 3	propham 6	2,4-DES 4	2,4-DES 8	fenuron 0.5	fenuron 1	diuron 0.5	diuron 1	neburon 2	neburon 4	chloroxuron 4	chloroxuron 8	chloramben 2	chloramben 4	simazine 0.5	simazine 1	prometryne 0.5	prometryne 1
ASTER (HHA)	D	R	R	-	-	R	S	-	-	-	-	R	R	(R)	S	R	R	R	S	-	-
(Callistephus)	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	S	S
CALENDULA	A	R	R	-	-	-	-	S	S	S	S	S	-	-	-	-	-	-	-	-	-
(HA)	B	R	R	R	R	R	(R)	S	-	-	-	R	R	-	-	-	-	-	-	-	-
	C	-	R	-	-	R	-	S	-	-	-	-	S	-	-	-	-	-	-	-	-
	D	R	R	-	-	R	S	-	-	-	-	S	S	S	S	R	(R)	S	S	-	-
	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	S	S
CHRYSANTH-	A	R	S	-	-	-	-	S	S	S	S	S	-	-	-	-	-	-	-	-	-
EMUM (HA)	B	R	R	R	R	R	S	R	-	-	-	R	R	-	-	-	-	-	-	-	-
	C	-	R	-	-	R	-	S	-	-	-	-	S	-	-	-	-	-	-	-	-
	D	R	R	-	-	(R)	S	-	-	-	-	(R)	S	R	S	R	S	S	S	-	-
	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	S	S
CORN-	A	R	S	-	-	-	-	S	S	S	S	S	-	-	-	-	-	-	-	-	-
FLOWER	B	R	R	R	R	R	R	(R)	-	-	-	R	R	-	-	-	-	-	-	-	-
(Centaurea	C	-	R	-	-	R	-	R	-	-	-	-	R	-	-	-	-	-	-	-	-
cyanus)	D	R	R	-	-	(R)	S	-	-	-	-	R	S	(R)	S	R	R	(R)	S	-	-
(HA)	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	S	S
GYPSOPHILA	B	S	S	S	S	R	R	S	-	-	-	R	R	-	-	-	-	-	-	-	-
ELEGANS	C	-	S	-	-	R	-	S	-	-	-	-	R	-	-	-	-	-	-	-	-
(HA)	D	S	S	-	-	S	S	-	-	-	-	S	S	S	S	(R)	S	S	S	-	-
	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	S	S

Table 2 (continued)

Summary of the results of 5 experiments with a range of residual herbicides, each at 2 doses on various hardy annual (HA), half-hardy annual (HHA) and biennial flower crops (R = resistant, (R) = borderline, S = susceptible)

Crop	Experiment	Chemical and dose (lb/ac) chlorpropham 1	chlorpropham 2	propham 3	propham 6	2,4-DES 4	2,4-DES 8	fenuron 0.5	fenuron 1	diuron 0.5	diuron 1	neburon 2	neburon 4	chloroxuron 4	chloroxuron 8	chloramben 2	chloramben 4	simazine 0.5	simazine 1	prometryne 0.5	prometryne 1
LARKSPUR (HA)	A	S	S	-	-	-	-	R	(R)	(R)	S	S	-	-	-	-	-	-	-	-	-
	B	R	R	R	R	R	(R)	R	-	-	-	R	R	-	-	-	-	-	-	-	-
	C	-	R	-	-	R	-	S	-	-	-	-	S	-	-	-	-	-	-	-	-
	D	R	(R)	-	-	(R)	S	-	-	-	-	R	(R)	(R)	S	R	R	R	(R)	-	-
	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(R)	S	(R)	S
SCABIOUS (HA)	A	S	S	-	-	-	-	S	S	S	S	S	-	-	-	-	-	-	-	-	-
	B	R	R	R	S	R	R	S	-	-	-	R	R	-	-	-	-	-	-	-	-
	C	-	R	-	-	R	-	R	-	-	-	-	R	-	-	-	-	-	-	-	-
	D	(R)	S	-	-	(R)	S	-	-	-	-	(R)	S	(R)	S	R	R	S	S	-	-
	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	(R)	S
STOCK (HHA) (Matthiola)	D	R	S	-	-	(R)	S	-	-	-	-	R	S	(R)	S	R	S	R	(R)	-	-
	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	S	S
SWEET PEA (HA)	B	R	R	R	R	R	R	S	-	-	-	R	R	-	-	-	-	-	-	-	-
	C	-	S	-	-	R	-	S	-	-	-	-	R	-	-	-	-	-	-	-	-
	D	R	R	-	-	R	R	-	-	-	-	R	R	R	R	R	R	R	R	-	-
	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	R	R	R
SWEET SULTAN (HA) (Centaurea moschata)	B	R	R	R	R	R	(R)	R	-	-	-	R	R	-	-	-	-	-	-	-	-
	C	-	R	-	-	S	-	S	-	-	-	-	R	-	-	-	-	-	-	-	-
	D	R	R	-	-	S	S	-	-	-	-	S	S	S	S	R	R	S	S	-	-
	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	S	S

Table 2 (continued)

Summary of the results of 5 experiments with a range of residual herbicides, each at 2 doses on various hardy annual (HA), half-hardy annual (HHA) and biennial flower crops (R = resistant, (R) = borderline, S = susceptible)

Crop	Experiment	Chemical and dose (lb/ac)																			
		chlorpropham		propham		2,4-DES		fenuron		diuron		neburon		chloroxuron		chloramben		simazine		prometryne	
		1	2	3	6	4	8	0.5	1	0.5	1	2	4	4	8	2	4	0.5	1	0.5	1
SWEET WILLIAM (B)	D	(R)	S	-	-	R	S	-	-	-	-	(R)	S	S	S	S	S	S	S	-	-
	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	S	S
TAGETES SIGNATA (HHA)	D	R	R	-	-	S	S	-	-	-	-	R	R	S	S	S	S	S	S	-	-
	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	S	S
WALLFLOWER (B)	D	R	R	-	-	R	(R)	-	-	-	-	R	S	(R)	S	R	R	(R)	S	-	-
	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	(R)	S
ZINNIA (HHA)	D	R	R	-	-	(R)	S	-	-	-	-	(R)	S	R	S	-	-	(R)	S	-	-
	E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(R)	S	S	S

Effects on weeds

The main aim of the trials was to determine the effects of the chemicals on the crop plants and plots were hoed where necessary before weeds grew large enough to compete with the crop. Some information on weeds was obtained, however, from observations on young seedlings made before hoeing.

In the very dry period following the spraying of experiment B, none of the chemicals gave adequate control. In experiment A, on the other hand, where the main weeds were Poa annua, Cerastium spp., Senecio vulgaris Stellaria media and Ranunculus bulbosus, relatively high percentage kills were noted in counts made in March. Chlorpropham was very effective against Poa, Cerastium and Stellaria but had little effect on Senecio, while diuron, fenuron and neburon were somewhat less effective on Poa, equally effective on Cerastium and Stellaria and more so on Senecio. Ranunculus was not controlled by any treatment. It was of interest to note that under the cold, wet conditions of this trial, diuron and neburon consistently gave slightly higher kills than fenuron. Mixtures of chlorpropham with fenuron or diuron (chlorpropham 1 lb + substituted urea 0.25 lb/ac and chlorpropham 2 lb + substituted urea 0.5 lb/ac) gave slightly higher kills of Senecio than chlorpropham alone, but even with the most effective mixture, the control was only of the order of 50%.

DISCUSSION

The results of these trials show that several common flower crops possess appreciable resistance to a number of residual herbicides. Members of the Compositae, such as aster, calendula, chrysanthemum, cornflower sweet sultan, tagetes and zinnia, are resistant to chlorpropham (also to propham where it was tested) and wallflower was also unaffected by this chemical. Gypsophila, however, was very sensitive to chlorpropham and sweet william, another member of the Caryophyllaceae, also proved relatively susceptible. The general resistance of the Compositae to chlorpropham and the susceptibility of the Caryophyllaceae noted with weeds thus appears to apply equally to flower crops.

Many of the species resistant to chlorpropham were also resistant to chloramben, though, from observations on weeds, resistance to chloramben appears to be less closely connected with taxonomic grouping. Some species, especially gypsophila and sweet william, proved susceptible to all the treatments tested and a few, such as larkspur and sweet pea showed exceptional resistance and even tolerated low doses of simazine. With sweet pea this is likely to be connected with deep sowing.

Insofar as the practical value of the treatments is concerned, chlorpropham is likely to be of use with species which are sown in the autumn, especially where Stellaria and annual grass weeds predominate and Senecio is absent. It can also give good results in spring, but is less reliable under warmer soil conditions when, as shown by Roberts and Wilson (1962), its persistence may be as little as 3 weeks. Propham is unlikely to have any great advantage over chlorpropham as, although the crops tolerate higher doses, higher doses are also needed to control the weeds. Mixtures of chlorpropham with fenuron or diuron are also unlikely to be greatly superior, because the addition of the substituted urea in amounts sufficient to improve the kill of Senecio, also increases crop injury.

It is probable that the majority of flower crops are sown in spring, rather than in autumn, and at this time of year chloramben appears to offer the most promise. 2,4-DES was tolerated by a number of species, but the safety margin was not high and the range of weeds controlled limited. Neburon also gave promising results in some trials, but caused much damage under wet conditions, thus indicating that the crops possessed very little true tolerance.

Of the chemicals that were tested as post-emergence treatments chlorpropham and 2,4-DES showed the most promise, but chloramben was not included in the post-emergence trial.

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PARAQUAT AS A PRE-EMERGENCE SPRAY FOR CONIFER SEEDBEDS

J.R. Aldhous
Forestry Commission Research Station, Farnham, Surrey

Summary In experiments in 1962-64, pre-emergence sprays of paraquat did not affect most of the commonly sown conifers. Only in one experiment was the yield of any species (Japanese larch) reduced significantly. The control of weeds achieved with paraquat at 0.5 lb a.i/ac (the recommended rate) was sometimes better and sometimes worse than that following sprays of vaporising oil.

All conifer species sprayed post-emergence were killed but pines and spruces took several weeks to react to post-emergence sprays.

INTRODUCTION

Vaporising oil, as a pre-emergence spray at 60gal/ac applied 3-4 days before the emergence of the crop, has been in general use in forest nurseries for the last twelve years. It has been most effective in this role especially with the slower-germinating conifer species. Paraquat has the similar properties of killing a wide spectrum of young weeds and having no effect after it has reached the soil, being rapidly inactivated there at least in soils containing some clay. A series of experiments in the years 1962-1964 have almost all shown that paraquat can be used safely as an alternative to vaporising oil.

Experiments were carried out in 1962, 1963, and 1964; on four species at Kennington, Oxford in 1962; on four species each on three sites in 1963 (Kennington, Oxford; Farnham, Surrey and Wareham, Dorset), and on thirteen species on nine sites (several species per site) in 1964. These sites included those used in 1963. Those experiments, laid down in 1962, 1963 and some in 1964, were carried out in Forestry Commission Research nurseries, specifically designed to test paraquat. Some of the 1964 experiments were carried out in Forestry Commission production nurseries on routine sowings. The soils in all the nurseries were acid or very acid, the pH (measured in water) ranging from 4.3 to 5.5. Many soils were sandy with very little or no content of clay.

In all experiments, several rates of applications were compared, and in all experiments in research nurseries the effect of date of application in relation to sowing and emergence was also tested.

METHOD AND MATERIALS

Paraquat was applied either by a small hand-held precision sprayer (working on the same principle as the Oxford precision sprayer) or a "Mysto" hand sprayer or a knapsack sprayer. The unit area sprayed in all the 1962 and 1963 experiments and in the more complex 1964 experiments, was 1 yd^2. In the simpler experiments carried out in production nurseries in 1964, the sprayed plots were 6 ft long and the full width of a seedbed (i.e. 3 ft or

Table 1

Number of Seedlings Assessed in Experiments Showing the effect of Paraquat pre-Emergence sprays on Conifer Seedbeds

Year	Nursery	Date: Sown	Spray	Emerge	Assess	Paraquat applied at (lb a.i/ac): ¼	½	1	1½	2	4	Control: Oil	Hand only*	S.Error
						Sitka Spruce								
1962	Kennington	12.4	6.5	11.5	7.6	-	-	177	-	160	178	158	-	± 13.5
1963	Alice Holt	20.3	26.4	30.4	28.6	-	140	119	146	140	-	128	-	± 12.3
	Wareham	23.4	10.5	16.5	5.7	-	121	149	126	151	-	124	-	± 13.1
	Kennington	16.5	30.5	4.6	1.7	-	172	176	186	169	-	185	-	
1964	Alice Holt	15.4	4.5	11.5	21.7	372	370	368	-	-	-	383	367	± 30.4
	Wareham	29.4	14.5	16.5	6.8	368	381	338	-	-	-	360	336	± 18.7
	Kennington	4.6	19.6	19.6	12.8	284	272	295	-	-	-	322	268	± 24.8
	Maelor	31.3	8.5	11.5	27.7	269	256	238	-	-	-	283	-	± 12.0
						Japanese Larch								
1962	Kennington	12.4	6.5	6.5	7.6	-	-	99	-	90	100	96	-	± 7.3
1963	Alice Holt	20.3	26.4	30.4	28.6	-	48	48	41	33	-	60	-	± 7.1
	Wareham	23.4	10.5	13.5	5.7	-	51	47	45	54	-	57	-	± 7.4
	Kennington	16.5	30.5	4.6	1.7	-	78	78	72	89	-	76	-	± 9.2
1964	Kennington	4.6	19.6	19.6	10.8	106	111	108	-	-	-	111	111	± 8.4
						Western Hemlock								
1963	Alice Holt	20.3	26.4	28.5	28.6	-	157	177	154	136	-	139	-	± 11.2
	Wareham	23.4	10.5	21.5	5.7	-	99	126	93	87	-	89	-	± 15.3
	Kennington	16.5	30.5	11.6	1.7	-	147	92	129	178	-	127	-	± 18.9
1964	Kennington	5.6	22.6	24.6	13.8	293	323	322	-	-	-	344	233	± 19.9
	Maelor	31.3	8.5	18.5	27.7	429	421	399	-	-	-	407	-	± 17.4
						Scots Pine								
1964	Roudham	7.4	27.4	30.4	28.5	205	218	216	-	-	-	241	-	± 13.6
						Corsican Pine								
1964	Roudham	10.4	27.4	30.4	28.5	139	126	131	-	-	-	114	-	± 9.1
						Beech								
1964	Ystwyth	14.4	7.5	7.5	28.6	10	10	10	-	-	-	13	-	± 2.1

*Hand Only = No herbicides used, plots weeded by hand only.

$3\frac{1}{2}$ ft). All treatments were replicated three or four times according to the particular experiment.

In all experiments in 1962 and 1963 there were four species on each sprayed plot, each species being sown on a strip 4 x 36 in across the plot, and being separated from neighbouring strips by 5 in of bare soil. In 1964 each sprayed plot was broadcast-sown with seed of one species only. The numbers of seedlings in 1962 and 1963 experiments given in the tables were obtained by counting all live seedlings in each 4 in x 36 in strip. The numbers shown in the 1964 experiments were obtained by counting those seedlings in five sample areas, each 2 in x 36 in taken from the broadcast-sown plots, i.e. two and a half times the area of the strips used in earlier experiments.

Seedlings have normally been counted twice during the growing season and once again after growth has finished for the year. The control of weeds has been assessed by the time taken to hand-weed plots during the early part of the growing season. Usually, the first two hand weedings showed the effects of the spray treatment: thereafter differences were lost. Times are shown in minutes per square yard.

The rate of paraquat used in each year's experiments varied according to the ideas at the beginning of the year of what was likely to be both an economic, effective and safe rate for general use. At present day prices a pre-emergence spray of vaporising oil costs between £5 and £6/ac (materials only). Paraquat at 1 lb a.i./ac would cost £3-5-0d. per acre.

RESULTS

Paraquat on the Crop

Table 1 gives representative results of the effect of paraquat on several species. Only in one experiment out of forty was there any significant reduction in the yield (or any other effect on the yield) of conifer seedlings following a paraquat pre-emergence spray. In this experiment at Alice Holt in 1963, the yield of Japanese larch seedlings was significantly reduced following a pre-emergence spray of paraquat at rates from 0.5 to 2 lb a.i/ac. In four other experiments Japanese larch was unaffected.

Date of Application

In the experiments in 1962 and 1963, all applications were made before any species germinated. In most experiments from 3 to 8 days elapsed between spraying and first germination. In 1964, attempts were made to see how close to the date of first germination, sprays could be applied without affecting the crop. All the evidence (except for the solitary instance of the Japanese larch already pointed out), indicates that spraying up to two or three days before seedlings first emerge is safe.

In the 1964 series of experiments, some treatments were applied post-emergence. While ultimately almost all sprayed seedlings died, several species took a long time to react to paraquat. This is illustrated in Table 2. All the pines, spruces and Douglas fir reacted slowly; on the other hand the larches, Western red cedar and Western hemlock, behaved much in the same way as the weeds present, most being straw-coloured and desiccated within a week of spraying.

Table 2

Number of Seedlings Assessed showing the Delayed Effect of Paraquat applied Post-emergence on Conifer Seedlings

Date Sprayed	Rate of Paraquat (lb a.i/ac) ¼	½	1	¼	½	1
	Corsican pine - Alice Holt Nursery, Sown 10.4.64 1st Emerged 24.4.64					
	Assessed 14.5.1964			Assessed 12.6.1964		
22/4	158	161	149	155	166	160
29/4	154	158	161	152	121	141
1/5	155	152	155	145	137	102
5/5	143	152	111	119	92	42
V.O/H.W	145/171			145/178		
	Norway Spruce - Wareham Nursery, Sown 29.4.64 1st Emerged 12.5.64					
	Assessed 9.6.1964			Assessed 5.8.1964		
11/5	364	372	359	358	362	352
15/5	302	272	137	201	172	93
20/5	349	296	235	291	240	79
22/5	340	170	81	121	36	26
V.O/H.W	356/343			344/353		
	Western Red Cedar - Wareham Nursery, Sown 30.4.64 1st Emerged 20.5.64					
	Assessed 8.6.1964			Assessed 6.8.1964		
19/5	174	147	142	206	176	191
22/5	148	134	109	187	182	154
27/5	88	69	64	123	108	78
2/6	10	0	0	29	30	22
V.O/H.W	170/170			226/181		

V.O. = Plot sprayed pre-emergence with Vaporising Oil at 60 gal/ac.

H.W. = Hand Weeding.

Weather at the time of Spraying

In Britain seed of all conifers and many hardwood species are almost invariably sown on the soil surface and covered with a lime and silt-free coarse sand or fine grit. To reach the soil and become inactivated, paraquat has to pass the seed. Obviously it is important to know if the germinating seed is threatened by paraquat sprays under any particular weather conditions.

Notes made at the time of spraying give no indication that any particular weather conditions enhance or reduce the value of paraquat as a pre-emergence spray. However, at the beginning of 1964 there was insufficient evidence of the possible action of rain washing paraquat into the soil. Experiments were therefore laid down, applying paraquat a 1 lb a.i. in 40 gal of water/ac and following this about 1 hour later by heavy sprays of water corresponding to 0.05 and 0.20 in of rain. These sprays were applied on the same dates as the experiments quoted in Table 2. Again, the pre-emergence sprays did no damage to the crop, with one possible exception, as shown in Table 3. In this case, the number of European larch seedlings on plots given the heaviest application of water following paraquat spraying was appreciably less than on other plots but this difference was not statistically significant. Table 3 shows that the watering treatment had no effect on the control of weeds.

Table 3

Effect of additional water following paraquat spraying on yield of seedlings (inches/ac) and weeding times. (Minutes/yd^2)

Nursery	Species	Additional Water/in 0	0.05	0.20	S.E.
		Number of Plants			
Kennington	Western hemlock	214	248	243	19.6
	Scots pine	178	155	158	14.8
Wareham	Norway spruce	342	338	343	13.5
	Sitka spruce	315	335	296	16.1
Alice Holt	European larch	150	138	110	22.0
	Douglas fir	120	175	119	24.01
		Weeding Times			
Wareham	Norway spruce	1.6	1.5	1.5	0.54
	Sitka spruce	2.6	2.8	2.5	0.52
Alice Holt	European larch	0.10	0.07	0.12	0.035
	Douglas fir	2.3	2.1	2.4	0.23

Weed Control

In all these experiments the control of weeds was measured by the time taken to hand-weed plots in the two months following spraying. Note was also made of all weed species present but none was found resistant to paraquat.

Table 4 gives the handweeding times in each experiment. The weeding times make an inconsistent picture because of the considerable random variation in weed growth from one plot to another and very few of the quite big differences apparent in the table are statistically significant. Sometimes vaporising oil appears to have worked better than paraquat at 0.5 or 1 lb/ac and sometimes the opposite has occurred. Vaporising oil is variable in composition and this could account for part of the difference in response.

In the 1964 experiments, the lowest rate tested, 0.25 lb a.i/ac has consistently given a poorer control of weeds than 0.5 lb a.i/ac. However, only at Alice Holt in 1964 is there any indication that 1 lb a.i/ac might be preferable to 0.5 lb a.i/ac.

In each of the Research nurseries in 1964, the time taken to weed the sprayed plots varied markedly from one experiment to another. This is partly due to some areas in each nursery being weedier than others but more to the different germination speed of different conifers. Those which germinated quickly, e.g. Scots pine, European larch, emerged at the same time as the earliest weeds. For these species, there was little benefit from any pre-emergence spray and there were many weeds to be removed by hand subsequently. The slower germinating conifers on the other hand, could be given an effective pre-emergence spray, whether of paraquat or vaporising oil.

DISCUSSION

The results given indicate that paraquat can safely be used on seedbeds of most common conifers as a pre-emergence spray. There is a slight uncertainty about the larches, and the possibility exists that under certain weather conditions, these species may sustain damage as germinating, but not yet emerged, seedlings. It has been mentioned already that many of the experiments were sited on acid sandy soils. Such soils contain very little or no clay particles and the fate of paraquat sprayed onto them is uncertain. These experiments indicate that there is little short-term risk from paraquat residues in such acid sandy soils.

No firm conclusion can be reached whether paraquat is more or less effective than vaporising oil as a pre-emergence measure for controlling weeds, Paraquat at 0.5 lb/ac seems sufficient to control weeds - there is little evidence that 1.0 lb/ac gives better control. At this lower rate, paraquat has a distinct cost advantage over vaporising oil but this advantage would be easily lost if subsequent evidence shows that it does not control weeds as well as vaporising oil.

Table 4

Time taken to weed plots sprayed with paraquat (Minutes per plot)

Year	Nursery	Species sown on weeded plots	Interval between sowing & spraying (days)	Rate of Application: Paraquat (lb a.i/ac.) $\frac{1}{4}$	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	4	Control: Vap. Oil	Hand Weed Only	S.E.
1962	Kennington	Four*		-	-	11	-	8	6	7.5	-	
1963	Kennington	Four*	14	-	0.5	0.2	-	0.2	0.5	0.3	-	0.4
	Wareham	"	17	-	3.8	3.6	-	2.4	2.3	5.9	-	
	Alice Holt	"	37	-	0.8	0.6	-	0.5	0.4	3.4	-	
1964	Wareham	Norway spruce	12	19.7	11.6	8.2	-	-	-	10.8	56.1	6.1
		Lodgepole pine	15	7.8	3.9	1.9	-	-	-	0.8	15.1	1.3
		Sitka spruce	15	14.6	11.3	7.2	-	-	-	4.2	34.6	1.4
		Western red cedar	19	5.5	4.2	5.1	-	-	-	3.5	17.0	2.0
	Alice Holt	Corsican pine	10	6.1	5.5	6.0	-	-	-	6.2	5.4	0.70
		European larch	10	5.0	5.8	4.8	-	-	-	4.9	6.9	0.54
		Sitka spruce	27	6.1	2.4	2.2	-	-	-	3.4	11.1	0.92
		Douglas fir	34	1.4	0.5	0.4	-	-	-	1.4	3.6	0.31
	Ystwyth	Beech	23	2.7	1.7	2.3	-	-	-	2.2	-	0.35
	Roudham	Scots pine	20	4.2	3.3	3.6	-	-	-	12.7	-	0.91
		Corsican pine	17	4.2	4.3	3.3	-	-	-	10.2	-	1.15

* Four species per plot: 1962 Sitka spruce, Japanese larch, Lodgepole pine, Douglas fir.
1963 Sitka spruce, Japanese larch, Western hemlock, Douglas fir.

WEEDKILLING IN YOUNG FOREST PLANTATIONS USING PARAQUAT

W. H. Jack

Forestry Division, Ministry of Agriculture, Northern Ireland.

Summary. Trials indicated that a single application of paraquat with a dribble bar at 1 lb active material per sprayed acre was sufficient to control weeds in young forest plantations for a year. Application with an Arbogard sprayer was more successful and 0.75 lb active material per sprayed acre on 4 square feet per tree appears to be quite satisfactory and cheaper than hand cutting in many instances. No significant increase in growth rate compared with the usual hand cutting was noted. In 10 year old crops where growth was decreasing control of vigorous heather and associated plants has given some growth response.

INTRODUCTION

Various trials with paraquat from May, 1961, suggested that this chemical might be used for weed control in young forest plantations. Jack (1964) Investigations were accordingly started to determine -

(1) the concentration required using a dribble bar (1963);
(2) the concentration required using an Arbogard sprayer (1964);
(3) the effect of weed killing on rather older stands of trees.

METHODS AND MATERIALS

Experiment 1

Paraquat was applied at three concentrations of 0.5, 1 and 2 lbs active material (2, 4 and 8 pints Gramoxone W) in 60 gallons of water per sprayed acre using a dribble bar in May/June, 1963 and again in May, 1964. Plots were single rows of trees 60 yd long with a 2 ft wide strip being treated on each side of the row of trees, care being taken to avoid letting any paraquat fall on the trees. Dead trees at time of application were removed.

Three completely different sets of conditions were considered, i.e.,

(a) Castle Archdale. Norway spruce (7 in - 12 in high in December 1962) planted in 1963 on land formerly rough grazed and ploughed with a single furrow Begg plough at 5½ ft spacing before planting. Weed growth was vigorous and was largely meadow grasses some 18 in high.

(b) Baronscourt. Sitka spruce (8 in - 22 in high in December 1962) planted in 1961 and beaten up in 1962 and 1963 on land from which trees were removed during 1957-1959. The Sitka spruce had been direct planted and there had been vigorous re-invasion of the site by soft grasses, largely Deschampsia spp, some 18 in high.

(c) Lislap. Sitka spruce (8 in - 17 in high in December 1962) planted in 1961 on peat land formerly under very rough grazing. The area was hand turfed for planting and the vegetation was largely heather, Calluna vulgaris, and other associated moorland plants with very few grasses, some 12 in high. Within each area the experimental design was a randomised block layout including an untouched control and a treatment by normal hand cutting.

Experiment 2

As a pressure sprayer had shown itself to be more effective than a drip sprayer provided the trees were not damaged a further trial was laid down in June, 1964, to assess the effect using an Arbogard sprayer as marketed by Messrs. Allman Patents, Ltd. Mixtures of 20, 40 and 80 ml of paraquat per gal of water applied at the Arbogard settings of 5, 10 and 15 (equivalent to spraying 1 sq. ft, 4 sq. ft and 9 sq. ft respectively round each tree) on a factorial layout giving 9 separate treatments with concentrations thereby ranging from 0.3 to 3.3 lbs active material paraquat per sprayed acre were applied. Only 2 site conditions were considered, at Castle Archdale and Baronscourt as in Experiment 1 above except that in Baronscourt the original tree crop had not been cleared until 1961 and replanting was with Norway spruce in 1962. Again randomised blocks were used within each site condition and plots were single rows of trees with trees dead at the time of application being removed.

Experiment 3

In an older area of Sitka spruce planted in 1955 on ploughed ground on peat and with a dense growth of vigorous heather and associated moorland vegetation it was obvious that tree growth was falling off although they averaged over 4 ft high. This area was treated during June and July 1963 by dribble bar and Four Oaks pressure sprayer to kill off ground vegetation in a 3 ft strip between each row of plants thereby covering just over 50% of the ground. Five plots were treated at concentrations from 0.5 to 2 lbs active material per sprayed acre and two control plots were also demarcated.

RESULTS

Experiment 1

For all three sets of environmental conditions it was obvious from a visual inspection that the heavier the concentration of paraquat the better the kill of weeds but the treatment at 1 lb active material was quite satisfactory in preventing weed damage to the trees. On re-planted ground at Baronscourt the 1963 treated area was quite obvious in June, 1964, and might well have been satisfactory without further treatment but at Castle Archdale the 1963 treated strips were not evident. The dribble bar did not give 100% control of heather but concentration at 2 lbs active material per sprayed acre killed off over 80% of the vegetation cover.

The mean 1963 and 1964 (to August, 1964 only and not therefore all 1964 growth) leader growth of the trees was measured but there were no statistically significant (P 0.05) differences in any of the environmental conditions tested. An interesting feature at Castle Archdale was that during 1964 the trees grass cleaned by hand only put on a mean of 2.0 in leaders while the paraquat sprayed plots generally grew at over 4.0 in and the control was 3.6 in mean. Virtually no trees were killed in any of the blocks.

Experiment 2

By August 1964 all treatments with the Arbogard where the sprayed area was 4 sq. ft or more appeared to be reasonably satisfactory. This included the lowest concentration of 0.3 lbs active material per sprayed acre although this did not give 100% kill and looking at any area it is possible to pick out the rates of concentration. None of the killed areas of weed growth is as big as the theoretical sprayed area of 1, 4 or 9 sq. ft due to the fairly tall vegetation intercepting the flow from the nozzle. No leader lengths have yet been measured in this experiment. No damage to the trees was noted and one treatment is probably all that is required whereas hand work in these areas often needs to be done two or three times per season.

Experiment 3

The paraquat has had an effect on the growth of the older Sitka spruce which are now a much better colour and the downward trend in leader growth has been reversed, see Table 1 below. The improved leader growth in plots treated by pressure sprayer is better than in those treated with the dribble bar, while the latter is better than the control. Differences in leader length in 1964 are not quite significant at P 0.05 although nearly so.

Table 1

Summary of mean leader lengths in inches of P.55 Sitka spruce sprayed June/July, 1963

Treatment	1960	1961	1962	1963	1964*
Control	8.0	7.6	3.4	1.2	1.7
Dribble Bar	8.5	8.6	4.6	2.2	3.0
Pressure Sprayer	8.7	7.4	4.7	3.9	5.0

* To 31st August, 1964 only.

DISCUSSION

It is obvious from these experiments that paraquat can be successfully used for a weed control in young forest plantations. Using a dribble bar concentrations of 1 lb active material per sprayed acre are probably required to give satisfactory control of the vegetation. Due to the quantity of water required for mixing at this application the economics of such a treatment depend very largely on the easy availability of water.

Treatment by Arbogard is much more successful and concentrations of 0.75 lb active material per sprayed acre are probably sufficient provided 4 sq. ft are sprayed round each plant. A single treatment will often suffice where two or more hand weedings would have been considered necessary. Other trials on the use of this sprayer suggest that up to 4,500 plants can be treated in one day and where 4 sq. ft sprayed is satisfactory and the trees are at the common spacing of 1,500 plants per acre this requires under 7 gal of water per planted acre for mixing; such treatment is likely to be considerably cheaper than hand weeding in areas where grass growth is vigorous.

Where growth on somewhat older trees is falling off and the native vegetation is reasserting itself increased growth of the trees can be obtained by weed control using paraquat. Unless the growth differences which are suggested in Experiment 3 above are maintained at an increased rate for some considerable time however the cost of this control is likely to be higher than manuring with fertiliser which is the more usual treatment.

References

JACK, W.H. (1964). The Results of Some Trials using Paraquat. The Forester. Vol.5 No.1. 31-32, July, 1964.

THE EFFECT OF PARAQUAT, 2,6-DICHLOROTHIOBENZAMIDE AND 4-AMINO-3,5,6-TRICHLOROPICOLINIC ACID ("TORDON") ON SPECIES PLANTED IN THE FOREST

J.R. Aldhous
Forestry Commission Research Station, Farnham, Surrey

Summary (a) Paraquat The bark of many conifers growing in young plantations is susceptible to damage by paraquat if applied in spring and early summer as could (and did) happen following use of a shield to enable paraquat to be applied close to young trees but avoiding foliage.

The foliage of conifers is killed by paraquat and many species sustain severe damage if sprayed overall with paraquat during the growing season. After growth has ceased, Sitka spruce, Norway spruce and *Abies grandis* become more resistant and are able to withstand overall sprays of 0.5 lb/ac. *Calluna vulgaris* (heather) is killed or very severely weaked by paraquat at 0.5 - 2.0 lb a.i/ac.

(b) 2,6-dichlorothiobenzamide formulated as a granule containing 7.5% a.i. has given good control of grasses and broad-leaved herbaceous weeds in the year of treatment when applied at 4-6 lb a.i/ac or more in April or May. Heavier rates of application often cause crop damage. Rates of 8 lb a.i/ac applied in spring or summer, control herbaceous weeds for most of the season in the year following application.

(c) "Tordon" has only been used in preliminary trials but these suggest that Tordon in water solution may be effective for controlling oak and ash but not hazel.

INTRODUCTION

This report describes five series of recent forest experiments carried out in England and Wales. In it, the response by the forest crop species has been emphasised and with one exception, only broad outlines given of the response by the many weed species present on the experiment sites.

Two of the herbicides tested, paraquat and 2,6-dichlorothiobenzamide have killed a very wide range of the herbaceous weed species present in the forest and could supplement or replace hand-weeding. (About one and a quarter million pounds were spent by the Forestry Commission in 1963, mainly on hand weeding herbaceous weeds in young conifer plantations). The third material, 4,amino-3,5,6-trichloropicolinic acid ("Tordon") was given a small-scale preliminary trial as an alternative to 2,4,5-T, testing it in water compared with 2,4,5-T in oil on species controlled by 2,4,5-T and comparing it with ammonium sulphamate on species resistant to 2,4,5-T. These tests constitute one of the series of experiments described here.

Three of the five series of experiments concern paraquat - not so much its effect on weeds as its effect, in specified circumstances, on tree crop. One series arose from the claims that have been made that a physical shield provides adequate protection to young trees (Lacey, 1964; Jack, 1964). Nevertheless in a trial of a prototype shield in the spring of 1963, in the Forestry Commission Research Nursery at Alice Holt, several trees were killed by girdling at the soil surface, apparently through the bark having been sprayed under the base of the shield. The other two arose from information from Northern Ireland which suggested that in late summer Sitka spruce could be sprayed overall and sustain negligible damage, and that good control of Calluna vulgaris (a weed which can check growth of spruces for long periods) could be achieved at the same time.

Three series of experiments with paraquat were therefore laid down testing (a) the effect of paraquat on bark of young conifers, (b) the effect of paraquat sprayed overall on conifer foliage and (c) the effect of paraquat on Calluna.

The experiments testing 2,6-dichlorothiobenzamide were designed to give information on both crop response and control of weeds under conditions in which it might be used in large-scale practice.

RESULTS

Paraquat on Conifer bark

Between March and September 1964, paraquat was sprayed or painted to run-off round the stem of a range of species, from ground level to a height of about 3 in. Two concentrations of paraquat solution were used, 1:800 and 1:400, corresponding to applications of 0.5 and 1.0 lb a.i. in 40 gal/ac.

Table 1 gives the health scores of treated trees, assessed in September, 1964. The table clearly shows that many species were severely damaged by the treatment applied between April and June, and that spruces were markedly less affected than other species. For most species it was impossible to say in September, when this assessment was made, whether trees with damaged bark would recover or die. The apparent increasing resistance to later sprays shown in the table may also turn out to be illusory in that in most cases several months elapsed before foliage became discoloured following death of the bark at ground level. It is quite possible therefore that trees treated late in the summer that did not show up in Table 1 as damaged, will deteriorate.

Paraquat overall spray

Eleven conifer and three hardwood species most commonly planted in the forest, were sprayed overall in 1963 using paraquat at 0.5, 1, 2 lb a.i. in 40 gal of water/ac. Sprays were applied by knapsack at one of six (or seven) dates, the first being in July and the next five at intervals of three weeks from the first. In N.Wales, paraquat was also applied overall to Sitka and Norway spruce in mid-January. Most of the spraying took place in the forest but several species were sprayed in Alice Holt research nursery. These plants were younger and smaller than the others.

There were three plants per plot in those experiments carried out in the forest. In the experiment at Alice Holt nursery, there were a minimum of ten plants per treatment. The health of all plants was assessed, two and six weeks after spraying and again during the growing season in the following year.

Sitka spruce (in the forest but not in the nursery), Norway spruce and Abies grandis were able to withstand a foliage spray at the rate of ½ lb of paraquat a.i/ac when applied between mid-August and mid-October, sustaining only a little scorch at the time and recovering subsequently. All three species similarly withstood sprays at 1 lb a.i/ac during this same period but at one or another time sustained quite heavy damage.

Three pine species, Lodgepole pine, Scots pine and Corsican pine generally were severely damaged by the two higher rates of paraquat, but those few individuals that showed only a little damage six weeks after spraying, survived and recovered in 1964. In contrast, Western red cedar and Lawson cypress apparently sustained more damage than could be seen six weeks after spraying; very few plants survived any treatment, even those assessed six weeks after spraying as showing slight or moderate damage to foliage only. The three hardwood species, beech, oak and sycamore, responded much more quickly than the evergreen conifers, being defoliated by the time they were assessed six weeks after spraying. Those plants which were not dead by this time subsequently recovered. Some assessed as dead six weeks after spraying, sent up basal shoots in the following year. European and Japanese larch and Western hemlock were also rapidly and severely defoliated but neither species recovered. Trees were more resistant to paraquat after shoot elongation had ceased, but younger trees continued to grow after older trees had stopped. Thus Sitka spruce transplants still growing in the nursery were severely damaged when older plants of the same species in the forest had hardened off and were more resistant. Plants which were growing rapidly not only were more susceptible but also showed the symptoms of paraquat damage within a few days of treatment. Most species sprayed in September or October on the other hand, did not always develop symptoms immediately. Many plants assessed two weeks after spraying showed little sign of damage but by the time the six week assessment was made, had deteriorated markedly. Those spruces sprayed in mid-January took even longer to show symptoms of damage; six weeks after treatment these plants looked little affected, yet when seen 10 weeks after spraying, the treated trees had quite a lot more brown foliage than adjacent untreated trees.

Paraquat on *Calluna vulgaris* (heather)

In both the two sites chosen for these trials (at Clocaenog and Ceiriog forests in N.Wales), Sitka spruce had been planted and had grown 18-48 in tall but was in check (i.e. was making slow growth and carrying yellow-green instead of blue-green foliage). The ground vegetation was dominated by *Calluna*, which was dense on both sites and had grown to about 18 in. There was also a little *Erica cinerea*, *Erica tetralix*, and *Vaccinium myrtilus*. *Festuca ovina* was present on the Ceiriog site.

Paraquat was applied at 0.5, 1 and 2 lb a.i. in 40 gal of water/ac in late July, mid August and early September, 1963 and in January 1964. The spray was applied overall, using a knapsack and spraying right up to the trees in the plot but not spraying over them (except where they were concealed under the *Calluna*). No guard was used to protect the young trees.

Table 2 gives the percentage reduction in ground cover (*Calluna*) on the two sites, assessed in September, 1964.

Table 1

The health score in September 1964 of trees treated at the root collar with paraquat in spring and summer 1964. (Application to bark, not to foliage)

Species	Location (Forest)	March ½	March 1	April ½	April 1	May ½	May 1	June ½	June 1	July ½	July 1	August ½	August 1
Scots pine	Thetford	Not		1	3	4	3	3	3	1	0	1	0
Corsican pine	Thetford	treated		3	3	4	4	3	3	1	3	0	0
Lodgepole pine	Gwydyr	3	3	2	3	1	4	3	3	1	2	1	1
Japanese larch	"	1	3	1	4	2	3	1	3	0	1	0	0
Sitka spruce	"	0	1	0	1	2	3	1	1	1	1	0	0
Norway spruce	"	1	1	1	1	0	2	1	1	0	1	0	0
Serbian spruce	Alice Holt	0	0	0	0	0	0	0	0	0	0	0	0
Western hemlock	" "	3	4	4	3	2	3	1	1	0	1	0	0
Western red cedar	Forest of Dean	1	4	4	4	3	4	0	4	1	0	0	0
Douglas fir	" "	1	0	0	0	0	1	0	0	0	0	0	0
European larch	" "	1	1	0	1	1	2	1	3	0	0	0	0
Sitka spruce	" "	0	1	0	1	1	3	0	0	0	0	0	0
Grand fir	" "	0	1	0	3	1	1	0	0	0	1	0	0
Western hemlock	" "	1	3	2	3	3	3	0	0	0	0	0	0

Month and Rate of Treatment

Footnote

Six trees were treated at each time of application. The figures in the table indicate the following:-

0 = Bark healthy (sometimes slightly thickened)

1 = Bark killed in patches on stem, or resin bleeding from bark, on from 1 to 3 trees. No trees completely girdled or markedly discoloured.

2 = From 4 to 6 trees damaged as described for 1 above.

3 = The bark of from 1 to 3 trees completely killed at ground level, or tree markedly discoloured and with moderate or severe resin bleeding from the treated bark, or tree dead.

4 = From 4 to 6 trees affected as described for 3 above.

In the table heading, ½ = sprayed with 1 : 800 dilution of paraquat as would be used when spraying ½ lb a.i in 40 gal water/ac;

1 = sprayed with 1 : 400 dilution of paraquat as would be used when spraying 1 lb a.i. in 40 gal water/ac.

Table 2

%Reduction in ground cover of Calluna vulgaris following overall spray with paraquat. Assessment - September, 1964

Rate of Paraquat (lb a.i/ac)	Date and Site (Cl = Clocaenog; Ce = Ceiriog)							
	Late July		Mid August		Early Sept.		Mid Jan.	
	Cl.	Ce.	Cl.	Ce.	Cl.	Ce.	Cl.	Ce.
½	75	60	80	60	80	60	50	25
1	95	85	95	85	95	85	50	50
2	97	90	97	90	97	90	50	60

On all plots treated in the late summer, there were a few plants with one or more healthy stems remaining. This was probably due to uneven spraying when treatments were applied. On plots treated in January, 1964, the Calluna had died back for between 2 and 4 in. at the top of all the shoots but there had been extensive shooting and recovery and no stems had been killed outright. The affected Calluna did not flower.

Of the other weed species present, Erica tetralix appeared to be resistant to paraquat. Vaccinium myrtillus was scorched in the autumn following treatment but had recovered completely by the end of the year following treatment. Festuca ovina appeared to have been killed out.

The crop, Sitka spruce, had responded to all the summer treatments. The colour of all the foliage was blue-green and the current year's needles appeared to be larger than on trees in untreated plots. There was no sign of increased height growth but other experience indicates that where spruce is released from check, the colour improves in the first year and any increases in height growth do not appear until the second year. Lateral branches caught by the paraquat had died back between 2 and 6 inches but foliage and trees were otherwise healthy and could not be said to have suffered unduly as a result of the paraquat spray.

2,6-dichlorothiobenzamide

A 7½% a.i. granular formulation of this compound has been used in all experiments laid down between 1962 and 1964. Granules were distributed by hand over patches a yard square, each with a tree in the centre, planted at least six months and usually more than a year before treatment.

In 1962, a preliminary unreplicated trial was laid down in July at Thetford on a site planted with Corsican pine and carrying a moderate growth of grasses, mainly Holcus mollis, Agrostis spp. and Agropyron repens together with a small proportion of mixed broadleaved weed species. Patches were treated at 2, 4 and 8 lb a.i/ac. There was good control of weeds in the first year (Aldhous, 1964) on patches treated at 8 lb/ac and these plots remained substantially free of weeds until the late summer of 1964 when there was a light but nearly full cover of seedling broadleaved weeds, mainly Sonchus sp. Patches treated at 4 lbs could still be distinguished in late summer 1964 but were completely recolonised by weeds. No reliable conclusions could be drawn about the response by the crop.

In 1963 trials were laid down at Bere Forest, near Fareham, Hants, and at Lynn Forest, near Kings Lynn, Norfolk. The former site was on a heavy clay and carried a rank growth of a wide range of weed species, dominated by grasses, in particular, Deschampsia caespitosa. It had been planted with Norway spruce in 1958. The latter was on a sand and at the time of treatment carried a moderate ground cover of grasses mainly Arrhenatherum elatius and Holcus lanatus with a little bramble and willow herb. It had been single-furrow ploughed (i.e. one ridge and furrow every 6 ft across the site) and planted with Corsican pine in 1962.

Table 3 gives the mean percentage ground cover at Lynn Forest in October 1963, and the number of plants which died in 1964 assessed in September 1964.

Table 3

Results from Lynn Forest - control of weeds and number of dead plants (Corsican pine)

Date of Application	Rate lb a.i/ac	Percentage ground cover in October, 1963					Number of dead plants September, 1964 (out of 20 per treatment)				
		0	1	2	4	8	0	1	2	4	8
May 1963		92	80	65	35	15	0	0	0	0	3
June 1963		75	75	55	15	15	0	0	0	1	1
July 1963		85	90	50	25	15	0	0	0	6	6

Good control of grasses and herbaceous broadleaved weeds was obtained on plots treated at 8 lb a.i/ac and quite satisfactory control on plots treated at 4 lb. Bramble was not permanently affected though some foliage was slightly yellowed. In October 1963, many of the Corsican pine at Lynn looked unhealthy on plots treated at 8 lb per acre. On other plots, trees survived though one or two looked yellow. Table 3 shows that a number of trees died in 1964 in plots treated at 8 lb/ac.

At Bere, a similar good control of weeds was obtained on plots treated at 8 lb a.i/ac. On plots treated at 4 lb, the control of weeds was not as good as at Lynn while very little response could be seen on plots treated at 1 and 2 lb a.i/ac. By the end of 1963, a number of trees on plots treated at 8 lb/ac had turned yellow. Responses were very slow to appear - an interval of two or three months between treatment and response being usual.

In 1964 experiments were laid down on Corsican and Scots pine at Thetford forest (Norfolk/Suffolk border), on Norway and Sitka spruce at Gwydyr Forest (Caerns), on Douglas fir and Western hemlock in the Forest of Dean (Glos), and on Corsican pine in Micheldever forest (Hants). 2,6-dichlorothiobenzamide was applied at 4, 6 8 and 12 lb a.i/ac in late April, May, June or July (except at Micheldever where treatments were applied in the first week in May, June, July and August).

Responses were similar on all sites. The following notes summarise the effects assessed in September, 1964.

Late April/early May treatments. Good control of herbaceous weeds was obtained on all patches treated at 6 lb a.i/ac or more and on almost all plots treated at 4 lb a.i/ac. Patches remained clear of weeds for the summer.

Late May/early June treatments. Control of herbaceous weeds was not as good as on patches treated on the earlier date, but plots treated at 6 lb a.i/ac or more were substantially free of herbaceous weeds.

Late July/early August treatments. On most sites, there was no visible response by the weeds to these treatments. (Mid-September assessment).

The young trees growing on the treated patches were generally unaffected by the lowest rates of application on all sites. Otherwise, the number of plants of all species which developed a characteristic discoloration increased with rate of application and was more marked the earlier in the year the herbicide was applied. Table 4 gives the number of discoloured Norway and Sitka spruce at Gwydyr forest and is typical of the results obtained in these 1964 experiments.

Table 4

Number of plants out of 30 per treatment, with markedly yellow foliage or yellow and dropping foliage, or brown foliage (dead plants)

Rate a.i/ ac.	Norway Spruce					Sitka Spruce			
	Date of Application								
	April	May	June	July	:	April	May	June	July
4	0	1	0	3	:	0	2	0	0
6	4	2	10	6	:	2	1	2	0
8	2	5	1	0	:	1	1	0	0
12	10	10	16	3	:	4	5	7	1

The yellowing or death of plants appeared late in the summer, in some cases three or four months after treatments were applied. Most affected plants were uniformly yellow green or olive green, with no zoning or gradation of colour either along needles or along the shoot. First and second year needles were usually equally affected though the latter were generally a darker shade of green than the current year's needles. The colour of the most severely affected plants remained yellow or olive green but became duller, like plants which have dried out. The needles on dead plants were a foxy red-brown.

Individual species showed special additional characteristics when examined in September, 1964. Norway spruce shoots drooped on badly affected plants before the needles turned brown. Also, the current year's shoots lacked strength, and could be so easily detached from the plant that in one instance a leading shoot and in another a lateral had fallen and were found on the ground near the affected plants. Other current shoots could very easily be pulled from the plants, and could be snapped across the main axis of the shoot like a carrot; the woody tissue in the stem had not matured (this was observed in mid-September when the shoots on healthy plants were firmly attached and had a mature woody core).

A small proportion of the Scots pine on treated plots exhibited a marked yellowing on the tips of the current year's needles which otherwise appeared healthy.

The foliage of some of the Western hemlock developed a very pale upper surface, as though it had been bleached. Part of the mesophyll in such needles was brown.

Woody broadleaved weeds on all sites have continued to grow with little check. Most grasses formed on the experimental areas have been killed except at Gwydyr where Anthoxanthum odoratum recovered after an initial check. At several sites, Carex spp. also appeared to recover after an initial check, as did Juncus spp. at Gwydyr and Viola sp and Mercurialis perennis at Micheldever.

4-amino3,5, 6-trichloropicolinic acid ('Tordon')

'Tordon' has been found to kill certain species resistant to 2,4,5-T or 2,4-D. Preliminary trials were made at Alice Holt forest in August, 1963, testing 'Tordon' at 1.4 and 2.8 lb a.i. per 100 gal of water, on oak, ash and hazel. The last were old coppice stools, each with several stems. The stems of the oak were 10 in diameter and were girdled and herbicide poured into the fresh girdle. The ash stems, somewhat smaller, were felled and the stumps treated; the hazel was left standing and the base of the stem treated (basal bark spray). There were also both untreated controls and oak and hazel treated with 2,4,5-T at 1.5 lb a.i. in 100 gal of diesel oil and ash stumps treated with ammonium sulphamate at 4 lb per gal of water.

Twelve months after treatment, the oak and ash had both been effectively controlled by 'Tordon' at both concentrations. The cambium of the treated oaks was dead from 6-12 in above the girdle to below ground level, although the trees still carried some live foliage in early October, 1964. The ash stumps were not completely dead but there were only one or two shoots per stump and these were weakly and unlikely to survive. Ash is resistant to 2,4,5-T.

'Tordon' applied as a basal bark spray had little lasting effect on the hazel. Some (smaller) stems in each stool died but on the remainder, the foliage, 12 months after treatment, was only a little distorted and the bark and cambium were live. The stools treated with 2,4,5-T were just about dead by this time.

DISCUSSION

The experiments on paraquat have to some extent confirmed what might have been expected knowing the properties attributed to paraquat. The severity of damage to trees following sprays to the bark is remarkable and so is the apparent resistance of Sitka spruce and one or two other species to overall foliage sprays applied after growth has ceased. Calluna vulgaris is one of the few woody species to be killed outright by a single moderate application of paraquat, and paraquat could compete with 2,4-D as a means of controlling Calluna in checked plantations.

The slow response to paraquat on the bark and also on the dormant foliage of some species must be taken as a warning to those who may use paraquat for forest weeding, not to draw too hasty conclusions from inspections of the work a few days after spraying. The weeds will be affected but a young conifer crop may take two or three weeks or even months to show damage caused by the paraquat.

The evidence from elsewhere is that paraquat can kill or cut back almost all the herbaceous weeds encountered in the forest, and it is likely that paraquat will become a valued aid to many foresters. These experiments emphasise the need to keep paraquat off the forest crop.

2,6-dichlorothiobenzamide has kept down herbaceous weeds for at least twelve months. The best control of weeds in the season of application has been achieved with applications in April or May. Mid-summer applications have taken their effect in the following year. Crop damage has been severe on plots treated at high rates early in the summer 1964, but the possibility of further damage appearing several months after application cannot be dismissed. The future of this herbicide in the forest depends on achieving consistant weed control with minimum crop damage.

Tordon could be a quite promising competitor with 2,4,5-T but more information on cost in use and effectiveness are required before firm conclusions can be reached.

Acknowledgments

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THE USE OF HERBICIDES IN A TREE AND SHRUB NURSERY

M.O. Slocock
W.C. Slocock, Ltd., Goldsworth Nursery, Woking, Surrey

Summary The nursery concerned has an area of 700 acres and includes a wide range of soil types, from a rich peaty to a light sandy loam; all are more or less acidic. Since 1957 several herbicides have been used to control weeds in a wide range of young trees and shrubs. Open ground in course of preparation for the cultivation of these plants has also been treated. Several methods of application have been tested, and their relative advantages assessed. Considerable importance has been attached to the economic advantages of chemical weed control. The development of specialised herbicides for this branch of horticulture may be expected.

RESIDUAL HERBICIDES

Although sodium chlorate had been used in very limited quantities to control weed growth in uncultivated areas, the first herbicides used on plots containing nursery stock were mixtures of chlorpropham and fenuron (Herbox Red 1 gal/ac). These were applied in a high volume spray at 100 gal/ac. Initial trials were limited to a small section of each plantation by spraying either a selected number of rows or a band at right angles to them; the latter technique was adopted wherever possible as it facilitated a comparison between a much larger number of varieties. Among the subjects treated were Rosa rugosa (unrooted and 1yr rooted cuttings), Lilacs in variety, Privet (Ligustrum ovalifolium, rooted cuttings), a number of varieties of Cypress (Cupressus Lawsoniana vars., 2yr transplanted cuttings) and a wide range of fruit and ornamental understocks, which included some unrooted hard-wooded cuttings. None of these showed signs of injury, but transplanted Rhododendron ponticum seedlings and unrooted cuttings of Box and Rosa multiflora, sprayed in February, were retarded. In general the sprayed ground remained free of annual weeds until early summer, when Senecio vulgaris was usually the first to germinate. It was found that a more effective control was achieved if the ground was sprayed within two days of a cultivation; weed suppression was markedly better in newly planted crops. Mixtures of dalapon, fenuron and chlorpropham (dalapon/Herbox Red 4·2 lb/1 gal/ac) were applied to Agropyron repens in nursery stock, but although deciduous crops suffered no damage when dormant, weed control was unreliable, and young and evergreen foliage suffered temporary injury.

Further trials involved the application of chlorpropham (40% miscible), 2,4-DES, a fenuron/2,4-DES mixture (Herbox blue 4lb/ac) and a number of mixtures containing different proportions of chlorpropham and 2,4-DES. It became apparent that an effective dosage of chlorpropham could be applied safely to nursery crops only during the dormant season; the young foliage of a wide range of subjects, including 1yr budded Roses and Prunus species at all ages, was damaged by the chemical. Although injury to the more fastigiate shrubs could be eliminated by the use of a directed spray, another residual herbicide was required to maintain annual weed control throughout the summer in the many cases where it was impossible to maintain effective coverage without injuring the crop. Trials were therefore carried out with formulations based on 2,4-DES, and although the rates applied, 1 - 3a.i.lb/ac in 100 gal water, caused no damage to the crops tested (Erica spp., transplanted layers of Lilac and Rhododendron, 3yr seedling of Common Cherry, Yew, Laburnum etc), the control achieved was limited to a period of five weeks under normal weather conditions and often failed to include Poa annua and Stellaria media. Rather better control and greater persistence were obtained with the fenuron/2,4-DES mixture, but several applications were again required to maintain weed-free conditions throughout the growing season. These in turn necessitated a considerable number of preparatory cultivations. The addition of chlorpropham to 2,4-DES enlarged the range of weeds controlled and also compensated for the latter's retarded activity during cold and dry weather. A rate of 1 a.i.lb/ac, added to the sprays already used during the summer months, achieved a rapid and effective elimination of S.media at all stages of growth without damaging the growing crop. Weed control, however, was not extended, and a more persistent chemical, simazine, was therefore investigated.

Simazine is now the most widely used residual herbicide in tree and shrub nurseries. Since 1960, when trials on a few selected items were initiated, this chemical has been applied to every subject grown in the nursery. It has been shown that the age of the plant material, the interval between planting and spraying, the soil type and the subsequent rainfall - as well as the genus, species and even variety of the subject - are involved in determining the crop's susceptibility. Another important aspect is the persistence required; nursery stock is frequently transplanted and circumstances may necessitate the growing of a susceptible subject on land previously treated with simazine. Thus, although an established Sycamore will tolerate an application rate of at least 6 a.i.lb/ac, species of Deutzia, Spiraea, Euonymus and many other flowering shrubs would be liable to suffer injury if planted on the treated ground before a substantial proportion of the active material had been removed by microbiological or chemical breakdown. In spite of intermediate cultivations, this source of damage was found in a less extreme form when hardwood cuttings of Privet (L.ovalifolium), planted in March, followed a plot of 1yr budded Roses to which 2 a.i.lb/ac had been applied during the preceding autumn; early leaves produced by the cuttings were clearly, if only temporarily, chlorotic. A further consideration affecting the optimum dosage is the interval between cultivations required for reasons other than weed control. For example, that between the planting and the budding of understocks may be as short as three months, and two reduced doses are applied after each operation in order to avoid a dangerous increase in the concentration of herbicide in the soil.

The dosage range of simazine now applied extends from 0·5 a.i.lb/ac to 2 a.i.lb/ac. Several species or varieties within species are susceptible to damage even at the lower rate, particularly when treated as young plants recently transplanted. Subjects to which simazine is not now applied in the nursery include species of Corylopsis, Deutzia, Euonymus, Forsythia, Hydrangea, Hypericum, Senecio, Spiraea, Syringa and Viburnum. Even within these genera, however, wide divergences of reaction to the herbicide are found. Thus Spiraea bumalda 'Anthony Waterer' has not been damaged by doses of 2 a.i.lb/ac, and there are records (Geigy 1959) of this variety resisting applications in excess of this; on the other hand S.froebelli shows marginal chlorosis, on light soils, after treatment with 1 lb 50% product per acre. The genera which appear to be most susceptible to injury throughout their range of commonly cultivated species are Deutzia, Euonymus, Syringa and Viburnum.

Roses and their understocks are perhaps the most resistant plants widely grown, although unrooted cuttings of simplex (R.multiflora) have been retarded by a dose of $1\frac{1}{2}$ a.i.lb/ac applied in the late spring. No comparable effect has been observed in cuttings of R.rugosa at Goldsworth, but damage to both rooted and unrooted cuttings elsewhere has been reported (Geigy 1959). At the rate most frequently applied ($1\frac{1}{2}$ a.i.lb/ac), however, the great majority of transplanted nursery stock is undamaged, and this dose is sufficient to control annual weeds during a normal growing season on a medium loam. The figure is reduced to 1 lb/ac on sandier soils and when applied to Acacias, Lavenders, Limes, Periwinkles and many varieties of Prunus, although higher doses can be applied safely to the latter if the spray is directed away from actively growing foliage. Unrooted cuttings of Privet, Poplars and Prunus, except P.cerasifera and P. munsoniana, have been retarded by this rate of application. The most troublesome annual weed in plantations treated with simazine is Urtica urens which may appear several weeks before other seeds germinate; once this weed is present, a dense coverage often develops very rapidly, particularly during September and a mild October. The present technique for the application of simazine involves an overall spray at 35 gal/ac. A higher volume has been found to be unnecessary and uneconomic and a lower insufficient to ensure a satisfactory dispersal of the chemical. The restriction of the spray to a narrow strip along the crop rows no longer appears culturally or economically worthwhile. The requirement for inter-row cultivations is reduced, and observations to date suggest that crop growth, under normal climatic conditions, is no less vigorous. The soil is treated as soon as possible after cultivations to produce a fine tilth have been completed. Weed suppression improves markedly if newly planted crops are sprayed almost immediately; equivalent control is obtained at a lower dosage, and the risk of crop damage thereby reduced.

Other residual herbicides which have been applied on a very limited number of nursery crops are neburon, 2,6-dichlorobenzonitrile (incorporated in the soil), diuron and a chlorpropham/simazine mixture. Recently planted 1yr seedlings of Common Cherry (Prunus avium), unrooted sets of Poplars (P. robusta and P.balsamifera) and a variety of unrooted cuttings (Rosa spp, Prunus spp., Quince and Ribes spp.) were undamaged by neburon at 8 lb/ac and 2,6-DBN at 4 lb/ac; the cuttings were also undamaged by the chlorpropham/simazine mixture at $2/\frac{1}{2}$ lb/ac. 3yr grafted deciduous Azaleas were undamaged by diuron at 4 lb/ac. Simazine and 2,6-DBN were more or less equally effective in controlling weed germination, but diuron and neburon were less effective at equivalent rates. The chlorpropham/simazine mixture gave good control on a single unreplicated plot.

CONTACT AND TRANSLOCATED HERBICIDES

Reference has already been made to the application of a dalapon/fenuron/chlorpropham mixture. In addition to the use of dalapon and amitrole for controlling perennial grasses during the preparation of ground for planting nursery stock, these materials have been used on the crop itself. Dalapon/chlorpropham mixtures at 5·1/0·5, 5·1/1·5 and 6·8/0·5 lb/ac, a dalapon/2,4-DES mixture at 6·8/1·5 lb/ac and dalapon/chlorpropham/2,4-DES at 5·1/1·0/0·5 lb/ac (all a.i.) were applied as directed sprays in dormant 1yr rooted cuttings of Blackcurrants and Common Mussel (Prunus insititia), Rhododendrons and Azaleas, and 4yr Yews respectively. Control of the perennial grasses was poor and evergreen foliage suffered localised damage if sprayed in error; annual weeds were suppressed. Dalapon, alone, at

3-8 a.i.lb in 100 gal/ac was also used to control perennial grasses in a variety of crops, but was very unreliable when applied as an overall spray in a dormant, deciduous plantation and often injurious when attempts were made to apply it as a directed spray among actively growing shrubs. In young trees, however, the higher dose gave effective control of both Agropyron repens and Agrostis stolonifera when applied during the summer, and good results were also obtained when these grasses were sprayed in deciduous Azaleas and 1, 2 and 3yr seedling Beech just before these crops came into leaf; this type of control was necessarily limited to late-growing crops.

Amitrole has been used only rarely in nursery stock, but gave excellent weed control without damage to the crop when applied in a simazine/amitrole mixture at 1/0·5 lb/ac to dormant deciduous Azaleas and Hydrangea paniculata. A 1/2 lb/ac mixture of the same constituents caused a slight amount of chlorosis on Azalea and more serious damage to Hydrangea, however. It is felt that amitrole is too non-selective at low dosage rates to be widely useful in nursery crops.

The development of the two contact herbicides diquat and paraquat has placed an important new technique at the disposal of the tree and shrub nurseryman. In February 1961, plots of Laburnum, (L.vulgare 2yr seedlings), Common Mussel, (1yr rooted cuttings), Red-twigged Lime, (Tilia corallina, rooted layers), and deciduous Azaleas were sprayed when dormant with paraquat at 0·25 and 1·0 a.i.lb/ac. Initial weed control was excellent at the higher rate, but regrowth took place and perennial grasses were well established again within six weeks of the spraying date. The only crop to be damaged was Common Mussel which was retarded by the heavier application and showed marked chlorosis in the young foliage; only slight chlorosis was apparent in the material treated at the lower rate.

Paraquat, and more recently a paraquat/diquat mixture, have since been used extensively as directed sprays during the growing season and as overall sprays during dormancy. Special equipment has been developed to deliver the herbicide accurately at the base of shrubs, either from a gravity fed 'dribble bar' or through a hooded fan jet at pressures of 25-30 p.s.i. Plots treated at various rates of application were assessed and it was found that a 3·6% v/v solution of the product (Preeglone Extra) was the minimum concentration to control established annual weeds. A range of solutions containing the product at 1·8-9% v/v was applied as a directed spray on established annual grasses and although the higher concentrations gave quicker kill, the long term effect showed no significant improvement. Dribble bar application is particularly suitable for the control of weeds in evergreen crops and the lower growing deciduous shrubs; specialised equipment is now available and the Allman 'Xpando' sprayer has already proved useful for accurate row crop treatment. Translocation of the chemical within woody perennials appears to be very limited, and injury to the foliage of an understock is not transmitted to the scion variety. The lower side shoots of young trees have been desiccated without affecting the growth of the main stem.

No damage has been observed in fully dormant deciduous nursery stock treated with paraquat or a paraquat/diquat mixture, (Preeglone Extra 3 pts/ac)., but care has been taken to avoid spraying the young branches of such plants as Laburnum, Acer negundo, Magnolia, Hamamelis and other soft wooded subjects. Overall treatments have been applied to Beech, Rosa rugosa (lyr rooted cuttings), and a number of seedling hardwoods, in early spring without injury to the crop; weed control appeared to improve when the spray was applied during very cold weather. The application of a contact herbicide is particularly useful in controlling weeds in unrooted sets of Willow and Poplar, in which soil disturbance and residual herbicides have been shown to have a retarding effect.

Mixtures of paraquat and simazine have been applied with great success to ground on which a few annual weeds have already become established. Simazine/paraquat 1/1 a.i.lb/ac gave weed control only slightly inferior to that achieved with the simazine/amitrole mixtures mentioned above, and it was more effective and persistant than an application of simazine alone at 4 a.i.lb/ac. Simazine/paraquat 1/0·25 lb/ac also gave promising results, but both mixtures inflicted significant damage on some dormant Common Mussel rootstocks; young foliage became chlorotic as it emerged, and the heavier dose retarded the crop considerably. The residual and contact herbicide mixture now used has the composition simazine/paraquat and diquat mixture 1½/1 a.i.lb/ac, and this is used in the autumn on a wide range of deciduous crops (Maple, Elm, Birch, Sorbus, etc.) which are to be left undisturbed throughout the winter. The addition of the contact herbicide appears to have no effect on the residual properties of simazine, and the same precautions are taken to prevent damage to susceptible varieties.

FUTURE DEVELOPMENTS

Although the herbicides discussed above are now extensively used in tree and shrub nurseries, there are still theoretical and practical problems to be solved. These relate to crop susceptibility, persistence and techniques of application. It is inevitable that, in a range of genera as wide as that propagated in the general nursery, some subjects will be found that are damaged by a single residual herbicide. It is unlikely that other substituted triazines will provide a solution as those investigated to date are more soluble than simazine and therefore more liable to inflict damage through both foliage and root uptake. Although certain specific tolerances remain to be fully tested in woody perennial crops, it would appear that only a chemical quite unrelated to the triazines may possess properties which will enable it to be used effectively in genera which have been shown to be susceptible to simazine. There is evidence to suggest that chloroxuron, which has been used successfully as a spring treatment in strawberries (Tenoran 8 - 10 lb/ac), a stage where crop injury has followed application of simazine, may prove useful in some woody ornamental crops (Michel 1963).

Reference has already been made to the risks inherent in the use of persistent residual herbicides on nurseries where crops are frequently transplanted. There also exists the danger that the concentration of these chemicals in annually sprayed soil will increase to such an extent that it will not be possible to grow certain susceptible crops on the land involved. Investigation into the persistence of simazine has shown that it varies widely according to soil type, rainfall and subsequent cultivations, and there are good reasons to use herbicides such as chlorpropham and atrazine during autumn and early winter. This practice has already been adopted in Holland.

The accurate application of liquid herbicides in evergreen shrubs and young trees presents obvious practical difficulties, and the development of granular herbicides such as those widely used in the U.S.A. is anticipated. This type of formulation also facilitates overall application during the growing period without risk of foliar uptake.

ECONOMIC ADVANTAGES

There is, of course, no doubt that chemical weed control in nursery stock is a most important labour-saving technique. Little capital investment in equipment is required, and although some chemicals are expensive, the economic advantages of including the application of residual, translocated and contact herbicides in the routine production programme of a nursery are both considerable and obvious. In an area of nursery stock, the type of soil, seed population and weather all play their part in determining both the cost of the weeding operation itself and the number of times that it must be carried out in any one plot. If, on a given acre, the crop is planted at intervals of 3' x 1' (14,520/ac), the rows are hand hoed four times during the growing season and monthly mechanical inter-row cultivations are also carried out, the total cost of the hand labour will be approximately £35 p.a., and that of the other work at least £15 p.a. Chemical treatment alone, with simazine at 1½ a.i. lb/ac, will cost no more than £8, and even if this is combined with a single hand hoeing and occasional inter-row cultivations, the total figure will not exceed £25. A comparable percentage reduction in cost has been achieved by the replacement of hand hoeing by the application of paraquat and diquat; work previously costing some £25 has been completed more effectively and rapidly for less than £13. Such economic advantages are, of course, based on the assumption that crop vigour is maintained, both in the short and long term; careful selection and application of each treatment is necessary to ensure this. Indiscriminate use of herbicides in nursery stock including individually valuable plants can only result in unnecessary expenditure, substantial crop injury and financial loss.

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DISODIUM METHYLARSONATE IN RUBBER CULTIVATION

P. Riepma, Kzn
The Rubber Research Institute of Malaya

Summary   Data are presented concerning the susceptibility of plant species to disodium methylarsonate (DMA) and the accumulation of arsenic in the bark of young rubber after spraying with this chemical. It is concluded that the use of DMA will be limited to the control of weed populations dominated by susceptible grass species, and it will not be suitable for the control of mixed populations.
Hevea brasiliensis showed resistance and this permits the use of DMA at an earlier stage of growth than would be possible with sodium arsenite.

INTRODUCTION

At present control of established ground vegetation in rubber cultivation in Malaya is obtained by hand weeding or by spraying with sodium arsenite or other herbicides. Ground covers of leguminous creepers, and the tree planting rows, are kept free of weeds until two to three years after budding; from then onwards in immature and mature rubber it has been common practice to keep the planting rows clean by regular spraying with sodium arsenite, for which purpose 10-15 lb/sprayed acre of sodium arsenite is used. Sodium arsenite is also used for blanket spraying where weed growth is too vigorous, using three to five rounds of sodium arsenite per annum, and shortly before replanting when areas are cleaned up preparatory to planting leguminous ground covers.

There are several disadvantages to the use of sodium arsenite apart from its mammalian toxicity. This chemical will cause bleeding of the rubber tree or peeling of the bark on contact, and moreover certain weed species show some tolerance and cannot be controlled easily, e.g. Ottochloa nodosa, Axonopus compressus and Scleria spp. Since sodium arsenite is cheap however, possible alternative herbicides should have distinct advantages, particularly:

(a) they should be able to control the most common weeds at low dosage rates.

(b) they should show no toxicity towards rubber so that the herbicide can be sprayed right up to the tree without hazard - of particular advantage in young rubber when weed growth is vigorous and costs of hand eradication high.

Both these aspects are considered in the paper presented herewith, in respect of the organic arsenical disodium methylarsonate (DMA). Previous work has shown that this herbicide is particularly effective at elevated temperature, (RUMBURG, et al, 1960), and it was thought that this might make it particularly suitable for tropical conditions.

METHODS

For testing the susceptibility of weeds to DMA experimental sites were chosen where weed growth was dense (complete cover) and vigorous, 1-6 ft high. In all the experiments reported DMA was applied as a 100% hexahydrate form, in rates varying from 0.9-27 lb/ac, using a knapsack sprayer provided with a small spray boom with two Teejet nozzles 12 in. apart and nozzle size 730154 or 730308. The gallonage applied was generally 25 gal/ac. The plot size used was normally 1/200 ac, but ranged up to 1/20 ac when more dispersed woody species were present. Further details of these experiments are given by Riepma (1964a, 1964b), and the results are presented in Table 1.

The susceptibility of rubber to DMA was tested in a number of experiments using a single nozzle, the stem of the rubber tree being thoroughly wetted with a solution containing 4, 8 or 16 lb/ac DMA in 100 gal water, to which 2 pints of Lissapol N had been added (Table 2). Experiments were carried out on young rubber trees at 0.5, 1, 2 and 4 years after budding, which were sprayed repeatedly at three monthly intervals with DMA. Regular observations were made for symptoms of bleeding or peeling of the tree bark, and samples of bark were taken and analysed for arsenic residues.

RESULTS

The reaction of weeds

In Table 1 the results of the reaction of the different species based on a large number of experiments have been recorded. Weeds that were present in most or all experiments included Axonopus compressus, Paspalum conjugatum, Paspalum scrobiculatum, Ottochloa nodosa, Digitaria longiflora, Ischaemum muticum, Ischaemum timorense and Eleusine indica, and for these species the dose required to give 90% control is given as the LD 90. Variations in the LD 90 figures are due to:

(a) the particular site: the degree of shade cast by the rubber trees present can materially affect herbicide efficiency (Riepma, 1964b). In full daylight the required dose is much higher than under partial shade.
(b) the interval between date of spraying and of observation (Riepma, 1964a).
(c) weather conditions.

For the many other weed species that were present less commonly on the experimental sites, and for which sufficient data is not available to give LD 90 figures, the lowest doses to give defoliation, yellowing of leaves etc. were noted, and are quoted in Table 1. It can be concluded that these particular species are moderately resistant to DMA. Indeed, while the grasses Axonopus compressus, Paspalum conjugatum, Ischaemum spp. and Digitaria spp., and the ferns Nephrolepis bisserata and Lygodium spp. are quite susceptible to DMA, the other species mentioned in Table 1 are much less so, and the dosage rates suggested for the latter may not be economical compared with sodium arsenite.

Table 1

The relative Susceptibility of Weed Species to DMA

Species	Height in ft	LD 90 dose required for Control in lb/ac	Approximate lowest dose required to cause defoliation
Grasses			
Axonopus compressus	1	1 - 6	-
Paspalum conjugatum	1 - 2	2 - 10	-
Paspalum scrobiculatum	1 - 2	approx 12	-
Ischaemum muticum	1½ - 2	4 - 12	-
Ischaemum timorense	1½ - 3	4 - 12	-
Digitaria longiflora	1 - 2	4 - 10	-
Digitaria sanguinalis	1 - 2	4 - 10	-
Ottochloa nodosa	2	-	20
Cynodon dactylon	½ - 1	-	20
Eleusine indica	1 - 2	-	20
Cyperaceae			
Scleria spp.	3 - 6	-	20
Cyperus spp.	½ - 2	-	20
Ferns			
Nephrolepis bisserata	5 - 6	4 - 12	-
Lygodium scandens	1 - 1½	6 - 12	-
Lygodium flexuosum	1 - 1½	6 - 12	-
Cyclosorus gongyloides	1 - 2	8 - 12	-
Stenochlaena palustris	2 - 3	-	12
Blechnum orientale	2 - 3	-	12
Dicotyledons			
Tetracera scandens	2	-	12
Melastoma malabathricum	2 - 4	-	12
Eupatorium odoratum	2 - 4	-	12
Ficus alba	4	-	12
Ficus fistulosa	4	-	12
Macaranga triloba	4	-	12
Borreria latifolia	0.5 - 1.0	-	16
Croton hirtus	0.5 - 1.0	-	16
Indigofera sp.	1 - 2	-	8

The reaction of rubber

The results of analysis of bark samples taken in the trials testing the toxicity of DMA to young rubber are given in Table 2. In the control plots the bark content of arsenic ranged from 0.2 - 1.7 ppm, and application of DMA resulted in a considerable increase in arsenic content, as the result of adherence of the spray to the bark. In the case of young trees with brown bark subsequent washing by natural rainfall evidently largely removes the spray deposit, for in Experiments 13, 14 and 29 determination of the bark arsenic content showed little residual effect. When sprayed over the green bark of very young plants however (Experiment 38) a considerable increase in arsenic content was found, even after one spray, and this effect was more persistent than with the older plants.

DMA caused no damage in all these experiments, no bleeding nor peeling of the bark was observed.

Table 2

The effect of spraying DMA on arsenic content in bark of Hevea Brasiliensis immediately after last spraying and a month after last spraying.

Expt. No.	Clone	Year of budding	Date of first spray	Number of times of spray -ing	DMA lb/ac a.i.	Bark thick-ness in mm.	ppm As immed-iately after last spray-ing	ppm As a month after last spray-ing
13/64	Tj 1 seedlings	-	Jan. 1964	3	0	6.06	0.5	0.6
				3	4	6.69	102	0.7
				3	8	5.69	130	1.0
	RRIM 701	1962	Jan. 1964	3	0	4.75	1.5	0.6
				3	4	5.25	47	0.4
				3	8	4.13	126	0.6
14/64	PB 5/51	1960	Jan. 1964	3	0	5.42	1.1	0.2
				3	4	6.17	32	0.8
				3	8	5.42	96	0.9
				3	16	5.92	174	0.9
29/64	RRIM 701	Jan 1963	April 1964	2	0	2.79	1.7	0.4
				2	8	2.38	82	0.2
				2	16	2.21	242	1.6
38/64	RRIM 605	18-24 Nov 1963	July 1964	1	0	-	0.2	0.6
				1	4	-	64	3.1
				1	8	-	151	4.6
				1	16	-	493	12.7

DISCUSSION

From the data presented in Table 1 it is evident that the use of DMA will be restricted to the control of a few weed species. The susceptible species, however, include some of the commonest weeds of Malayan rubber and oil-palm plantations. It may be of particular value in oil-palm for controlling Paspalum conjugatum as amitrole is dangerous in this crop, while preliminary observations indicate considerable tolerance of DMA. Further work will be needed, however, to determine whether arsenic residues can appear in the palm oil.

The fact that DMA is tolerated by crops such as oil palm and rubber, in contrast to sodium arsenite, will be of particular advantage since spraying in planting strips can be started earlier than in the case of sodium arsenite. On the other hand the fact that only a limited number of weed species are susceptible to DMA will restrict its use against mixed populations requiring a blanket spray.

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